

DISTRIBUTION OF SEASONAL TRAINING INTENSITY
IN COMPETITIVE MASTERS-LEVEL
CROSS COUNTRY SKIERS

By

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ABSTRACT

Professionals have long debated the optimal distribution of training volume and intensity necessary for improved performance by endurance athletes. Although researchers have studied the training distributions of high-level cross country (XC) skiers, the unique population of Masters-level XC skiers has been largely overlooked. Therefore, the primary purpose of this study was to characterize the changes in Masters-level skiers' training volume and intensity from the fall to mid-winter seasons using telemetry-based heart rate (HR) monitoring. The secondary purpose was to determine the relationship between winter training variables and race speed within the same population. Fifty-six Masters-level skiers volunteered to don a HR monitor and utilize a training log to record all bouts of physical activity over two 14+ day periods designed to correspond with the preparatory (fall) and pre-competition (mid-winter) seasons. After the mid-winter collection period, the same subjects recorded HR data while competing in a 34.4 km ski race. All HR data were downloaded to a computer and summarized by absolute training time (T, min) and relative time (%T) spent within six HR zones (Z) which were calculated as percentages of age-predicted maximum HR (APMHR). Training variables were compared using two-factor and three-factor multivariate repeated measures ANOVAs, whereas winter training variables and race HR variables were correlated with race speed using the Pearson product-moment correlation. Only 13 men (Mean±SD: 62±5 yrs.) and 15 women (50±5 yrs.) completed all of the study requirements. From the fall to winter seasons, weekly training volume was maintained (Mean±SE: 515.7±24.2 vs. 514.8±31.7 min/week, respectively), but average training HR significantly increased (117±2 vs. 123±2 bpm, respectively). Moreover, there was a significant decrease in the %T spent training <70% of APMHR and a significant increase in the %T spent training ≥70% from the fall to winter seasons (53.0±3.6% vs. 40.2±3.1% and 47.0±3.6% vs. 59.8±3.1%, respectively). Additionally, the skiers' distribution of training intensity within each season tended to follow a threshold based model, as opposed to the polarized model followed by high-level endurance athletes. While characterizing these training practices helps build the knowledge base necessary for improved coaching of this population, further observational and experimental research is warranted.

CHAPTER ONE

INTRODUCTION

An Introduction to the Problem

Periodized distribution of training volume and intensity throughout the year is an area of continuous debate among coaches, athletes, and physiologists. While there is a great deal of research available on the benefits of untrained subjects exercising primarily at threshold (i.e., the threshold-training model) (Denis et al. 1984; Gaskill et al. 2001; Londeree 1997), a polarized-training model is more popular among elite athletes (Enoksen et al. 2011; Neal et al. 2013; Seiler and Kjerland 2006; Steinacker et al. 1998). Contrary to the threshold-training model, polarized training involves the vast majority of training time (> 75%) spent below the athlete's lactate threshold (LT_1), with the remaining time spent distinctly above lactate turnpoint (LT_2) (Seiler and Kjerland 2006). In order for coaches and athletes to develop effective training strategies, current training practices of the population must first be understood (Kennedy and Bell 1996). Collecting exercise heart rate (HR) data using telemetry-based heart rate monitor (HRM) systems is one method of characterizing an athlete's training practices (Achten and Jeukendrup 2003; Seiler 2010; Seiler and Tønnessen 2009).

Seiler and Kjerland (2006) collected HR data from 12 nationally competitive Norwegian junior skiers over 32 days. Heart rate data were divided into three training intensity zones demarcated by each subject's ventilatory threshold (VT) and respiratory compensation threshold (RCT). These physiological markers were defined as an increase

in $V_E \cdot \text{VO}_2^{-1}$ without an increase in $V_E \cdot \text{VCO}_2^{-1}$ and an increase in $V_E \cdot \text{VO}_2^{-1}$ with a concurrent increase in $V_E \cdot \text{VCO}_2^{-1}$, respectively. The athletes' training followed a polarized training model, during which they performed $75 \pm 3\%$ of their training sessions below VT and $17 \pm 4\%$ of training above their RCT. The same physiological cut-points were used in a similar six-month macrocycle study of sub-elite endurance runners (Esteve-Lanao et al. 2005). Although the sub-elite runners did spend the majority of their training time below VT (71%), they spent more time training time between VT and RCT (21%), and less time training above their RCT (8%) when compared to the junior skiers (Esteve-Lanao et al. 2005).

Although training volume and intensity are often described as distributional characteristics over the course of an entire season, researchers have also focused on the variation in volume and intensity distribution within a training season (Guellich et al. 2009; Neal et al. 2011; Zapico et al. 2007). Training periodization allows coaches and athletes to divide the season into smaller and smaller subunits, each with a specific training goal (Issurin 2010; Seiler 2010). The most common approach to periodization utilizes macrocycles which divide the athlete's training season into three major training periods: the preparatory, competition, and transition phases. These macrocycles can then be broken down further into mesocycles, microcycles, and individual workouts (Issurin 2010; Seiler 2010).

Neal and colleagues (2011) conducted a study on Masters-level Ironman triathletes during the six months preceding competition. This preparatory phase was broken down into three two-month training periods (A, B, and C, corresponding to the 4-

6, 2-4, and 0-2 months prior to competition, respectively). Similar to the aforementioned training zones based on VT and RCT (Esteve-Lanao et al. 2005; Seiler and Kjerland 2006), this study had three intensity zones defined as below LT_1 , between LT_1 and LT_2 , and above LT_2 for zones 1 – zone 3, respectively. The researchers found that there was a significant increase in absolute training time spent in zone 1 from periods A to B and a significant decrease in relative training time spent in zone 2 from periods A to C. Moreover, there was a general trend for total training volume to decrease from periods B to C despite a slight increase in absolute training time spent in zone 3 (Neal et al. 2011). Other studies have found similar increases in polarization as athletes near the competition macrocycle (Guellich et al. 2009; Zapico et al. 2007).

While many researchers have studied elite, junior, and/or recreational skiers, the unique population of competitive Masters-level cross country skiers has been largely overlooked in the research literature (Fabre et al. 2008; Hoff et al. 1999; Sandbakk et al. 2011; Seiler and Kjerland 2006; Vergés et al. 2003). American Cross Country Skiers (AXCS) defines Masters-level cross country skiers as non-professional Nordic (cross country) skiers, 25+ years old, of any ability level (American Cross Country Skiers [AXCS] n.d.). In the 2012 American Birkebeiner, the largest cross country ski race in North America and the fourth largest cross country ski race in the world, 82.5% of the 7,776 finishers were categorized as Masters-level skiers (American Birkebeiner Ski Foundation, 2012).

These endurance athletes experience an inevitable decline in performance as they age beyond their peak years, however, the processes by which athletic performance

deteriorates is a fairly new area of research (Lazarus and Harridge 2007; Young et al. 2008). In review articles by Lazarus and Harridge (2007) and Suominen (2011), physiological peak is defined as the point in an athlete's career when the combination of factors contributing to performance (maximal oxygen uptake, strength, power, speed, muscle mass, etc.) are at a maximum. This point tends to occur sometime between the ages of 25 and 35 in endurance athletes. Race performance steadily decreases from age 35 to 70 and exponentially declines thereafter (Lazarus and Harridge 2007; Suominen 2011). Studying competitive Masters athletes beyond their physiological peak helps better determine which physiological factors decline with inherent aging and which variables are due to reduced quality and/or quantity of physical activity (Lazarus and Harridge 2007; Suominen 2011).

Young et al. (2008) performed a study on 10 km running performance in elite, 40-59-year-old Masters-level runners. The researchers factored in age, current training practices, cumulative running during the five years prior to the study (time and mileage), and cumulative running earlier in a runner's career (running that occurred more than five years before the study). Current training practices accounted for more variation in 10 km running performance than age alone. Similarly, the researchers noted that cumulative running earlier in a runner's career also accounted for more of the variation in performance than age alone (Young et al. 2008).

Despite the large number of competitive Masters-level cross country skiers, there has been little research conducted on how these individuals currently train. To our knowledge, this is the first study to focus on characterizing the training distribution

practices of competitive cross country skiers beyond their physiological peak. Evaluation of the seasonal training practices of competitive Masters-level skiers will begin building the knowledge base necessary for improved coaching of this unique population.

Purpose

The primary purpose of this study was to characterize the changes in training volume and intensity of competitive Masters-level cross country skiers between the fall and mid-winter seasons. The secondary purpose of this study was to determine the relationship between mid-winter training intensity and racing speed.

Hypotheses

Primary Research Hypothesis

It was hypothesized that there would be an increase in exercise intensity (I) and a decrease in training volume (V) between the fall (F) and mid-winter (W) collection periods. The null hypothesis (H_0) stated that there would be no change in exercise intensity or training volume between fall and mid-winter training. The alternative hypotheses stated that there would be an increase in exercise intensity (H_{A1}) and a decrease in training volume (H_{A2}) between fall and mid-winter training.

$$H_0: \mu_{F(IV)} = \mu_{W(IV)}$$

$$H_{A1}: \mu_{F(I)} < \mu_{W(I)}$$

$$H_{A2}: \mu_{F(V)} > \mu_{W(V)}$$

where μ_F and μ_W represent population means for the fall and mid-winter, respectively, the subscript “I” represents exercise intensity, and the subscript “V” represents training volume.

Secondary Research Hypotheses

It was hypothesized that there would be a positive correlation between mid-winter (W) training intensity (I) and average race speed (S) during the 2014 Boulder Mountain Tour (BMT). The null hypothesis (H_0) stated that there would be no correlation between mid-winter training intensity and average race speed, whereas the alternative hypothesis (H_A) stated that there would be a positive correlation between mid-winter training intensity and average race speed.

$$H_0: C_{W(IS)} = 0$$

$$H_A: C_{W(IS)} > 0$$

where $C_{W(IS)}$ is the correlation between mid-winter training intensity (I) and average race speed (S) during the BMT.

Assumptions

It was assumed that the subjects logged all bouts of physical activity during the two data collection periods and did not alter their workouts as a result of being monitored. Additionally, it was assumed that telemetry-based HR monitoring was an accurate tool for recording free-living HR responses to exercise.

Limitations

1. Subjects were told to wear the HRM for every bout of physical activity over the course of a 14-day period. However, forgetfulness, HRM collection error, and/or user error were all sources of inaccuracies during the data collection process.
2. The use of the traditional 5-zone method based upon percentages of age-predicted maximum heart rate (APMHR), as opposed to measured physiological markers such as VT, RCT, maximal oxygen uptake (VO_{2max}), LT_1 , and/or LT_2 , did not allow for accurate comparison between cross country skiing populations in which training intensity distribution was well documented.
3. Due to scheduling conflicts and a rolling subject recruitment period, the fall data collection period (July 29th, 2014 to November 13th, 2014) did not occur during the same time of year for all subjects.
4. Characterizing training patterns from two collection periods (7-14 days in length) may not have been an accurate representation of fall and mid-winter training volume and/or intensity.

Delimitations

This study was delimited to subjects who:

1. Considered cross country skiing their primary winter sport.
2. Resided in the Pacific Northwest region of the United States, primarily Bozeman, Montana; Jackson, Wyoming; Park City, Utah; and Sun Valley, Idaho.

3. Were ≥ 40 years of age and free from health-related contraindications to vigorous exercise training.
4. Recorded HR response for $\geq 70\%$ of their logged training time during both the fall and mid-winter collection periods.
5. Competed in the 2014 Boulder Mountain Tour 34.4 km skate ski race in Sun Valley, ID. The purpose of HR data collection during the race was primarily a means of classifying the athlete (i.e., competitive) and secondly for comparison of intraindividual mid-winter training with racing speed (Esteve-Lanao et al. 2007; Esteve-Lanao et al. 2005).

Definitions

Competitive: An adjective used to describe athletes who train year-round and perform to the best of their abilities when racing.

Heart rate (HR): The number of times a heart muscle contracts during one minute, measured in beats per minute.

High intensity: Exercise that occurs above the LT_2 , RCT, and/or above a 10 km race-pace. This exercise intensity cannot be sustained for an extended period of time.

Lactate threshold (LT_1): The point at which lactate first begins accumulating in the blood.

Well trained endurance athletes are typically able to sustain exercise intensities at or near LT_1 for an extended period of time.

Lactate turnpoint (LT_2): The point when lactate accumulation exceeds the rate of lactate clearance and subsequent hydrogen ion (H^+) concentration increases

exponentially. At this point, the blood becomes more acidic and the body is no longer able to perform normal physiological responses at the cellular level.

Low intensity: Exercise that occurs below the LT_1 , VT , and/or below a 10 km race-pace.

This exercise intensity can typically be sustained for an extended period of time.

Macrocycle: A training period that lasts for several months, contains multiple mesocycles, and numerous individual exercise bouts. Macrocycles of endurance athletes are often broken down into the preparatory, competition, and transition training periods.

Masters-level skiers: Nonprofessional cross country skiers, 25+ years old, of any ability level. These athletes are typically split into age categories (25-29, 30-34, 35-39, 40-44, etc.) and separated by gender. For the purposes of this study, Masters-level skiers referred to individuals over 40 years of age who were categorized as either younger or older athletes (<56 and > 55 years of age, respectively).

Periodization: A method of organizing a training program into smaller and smaller goal-specific subunits, all centered upon the athlete's competition season.

Polarized training model: An approach to endurance training that focuses on low and high intensity exercise bouts, with little to no time spent at threshold.

Respiratory compensation point (RCT): An increase in the ventilatory equivalent of oxygen ($VE \cdot VO_2^{-1}$) in conjunction with a simultaneous increase in the ventilatory equivalent of carbon dioxide ($VE \cdot VCO_2^{-1}$). The respiratory compensation point is also known as second ventilatory threshold (VT_2).

Threshold training: Moderate intensity exercise which is often bound by physiological markers such as a HR value associated with LT_1 or VT (lower bound) and LT_2 or RCT (upper bound). When these physiological markers are unavailable, as is the case during this study, threshold training refers to exercise that mimics an individual's race-pace for a set duration of time (usually ≥ 20 min). For competitive endurance athletes, this pace is often described as hard, yet attainable.

Threshold training model: An approach to endurance training that splits relative training time between low and moderate intensity exercise bouts, with little to no time spent at higher training intensities.

Time logged: The average weekly training time a subject documented in their training diary during a specific collection period.

Time recorded: The average weekly training time collected on a subject's HRM during a specific collection period.

Traditional six training zones: The categorization of HR training data into six training intensity zones (Z0 – Z5) based upon percentage of APMHR without reference to LT, VT, or VO_{2max} .

Training intensity: The cardiovascular stress that occurs during an exercise bout, characterized by the time spent within each of the six training zones (Z0 – Z5).

Training volume: The average amount of time spent exercising each week (logged or recorded) during a specific collection period.

Ventilatory threshold (VT): The point at which $VE \cdot VO_2^{-1}$ increases without a concurrent increase in $VE \cdot VCO_2^{-1}$.

Operational Definitions

Age-predicted maximum heart rate (APMHR) was calculated using the following

equation: $APMHR = 208 - (0.7 \cdot \text{age})$ (Tanaka et al. 2001).

The following cut-points were used to demarcate the six HR training zones:

- Zone 5 (Z5) was the highest exercise training zone and included HRs $\geq 90\%$ of APMHR.
- Zone 4 (Z4) included HRs $\geq 80\%$ but $< 90\%$ of APMHR.
- Zone 3 (Z3) included HRs $\geq 70\%$ but $< 80\%$ of APMHR.
- Zone 2 (Z2) included HRs $\geq 60\%$ but $< 70\%$ of APMHR.
- Zone 1 (Z1) included HRs $\geq 50\%$ but $< 60\%$ of APMHR.
- Zone 0 (Z0) was the lowest exercise training zone and included HRs $< 50\%$ of APMHR.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Competitive Masters-Level Athletes

American Cross Country Skiers (AXCS) is the United States membership association for Masters-level cross country skiers and is recognized as the US representative for the World Masters Association (WMA). Whereas AXCS recognizes Masters-level athletes as citizen skiers 25+ years-old, the WMA recognizes Masters-level skiers beginning at age 30 (American Cross Country Skiers [AXCS] n.d.). Per international guidelines, National Ski Team members are ineligible to compete at the Masters-level. Athletes are split into age categories (30-34, 35-39, 40-44, etc.) and separated by gender (World Masters Cross Country Ski Association [WMA] 2012). For the purposes of this study, Masters-level skiers refers to individuals over the age of 40, thereby allowing the researchers to assume the athletes are past their physiological peak (Lazarus and Harridge 2007; Louis et al. 2012).

Despite many potential confounding factors (such as socioeconomic, environment, and nutrition), the most important variables in the human aging process are disuse, increasing sedentariness, and a decline in the quality and/or quantity of exercise bouts (Lazarus and Harridge 2007; Suominen 2011; Zamparo et al. 2012). Because there are many pathological conditions studied within the field of geriatric medicine, it is essential to differentiate between the conditions associated with aging (e.g., obesity,

cardiovascular disease, metabolic syndrome, etc.) versus inherent aging, the biological process of getting older.

Many researchers have labeled Masters athletes the optimal subjects for studies on the process of inherent aging (Bortz and Bortz 1996; Lazarus and Harridge 2007; Suominen 2011; Tanka and Seals 2003). The ability for researchers to automatically control for disuse (providing athletes are training regularly in their sport) allows for a better understanding of the natural aging process. In an early study on Masters athletes, Menard and Stanish (1989) observed decreases in overall marathon running performance (increases in race time) that the researchers attributed to the inherent aging process. Despite Masters athletes training to their maximum potential in order to win Masters championship races, it is clear that athletic potential is limited by age-related performance factors such as decreased cardiac output (Q), maximal oxygen uptake (VO_{2max}), and power output (Lazarus and Harridge 2007; Suominen 2011; Zamparo et al. 2012).

Maximal oxygen uptake is a major determinant of endurance performance (Holloszy 2001; Leyk et al. 2007). Unfortunately, despite any amount of endurance training, VO_{2max} will eventually decrease with age (Brooks et al. 2005). Bassett and Howley (2000) stated that the single most significant factor in determining VO_{2max} is Q , the product of heart rate (HR) and stroke volume (SV). Adolf Fick, a pioneer in hemodynamic and diffusion research, suggested that oxygen consumption is the product of the difference in oxygen concentration levels in the blood upon entering and leaving an organ (the lungs) and the rate at which the blood is flowing (Geerts et al. 2011). This

equation, known as the Fick equation, can be altered from submaximal to maximal conditions to read $VO_{2max} = Q_{max} \cdot (A-VO_{2\ diff})_{max}$, where Q_{max} is maximal cardiac output and $(A-VO_{2\ diff})_{max}$ is the maximal arteriovenous oxygen difference (Bassett and Howley 2000). According to Holloszy (2001), changes in Q_{max} account for the majority of the 1% decrease in VO_{2max} per year (from age 35-70) in Masters-level endurance athletes.

The degree to which VO_{2max} declines with age is still debated (Leyk et al. 2007). While some researchers have suggested a decline of less than 5% per decade, others have reported declines closer to 15% (Bortz and Bortz 1996; Leyk et al. 2007; Marti and Howald 1990). Leyk and colleagues (2007) analyzed 300,757 race time results from 60 marathons and 65 half-marathons that occurred between 2003 and 2005. While the age of racers ranged from 20-79, there were no dramatic declines in race performance noted until age 50 when race performance declined 2.6-4.4% per decade thereafter. Although the researchers could not directly link this decline to an equivalent decrease in VO_{2max} , they did suggest that the inconsistencies reported by prior researchers may have may have been the result of confounding factors, such as the typical decreases in physical activity associated with aging.

Despite the age-related decline in VO_{2max} , Masters-level athletes are still capable of maintaining higher levels of exercise intensity than untrained individuals (Kusy et al. 2012). In a study by Kusy et al. (2012), researchers measured the gas exchange threshold (GET) in 199 men (20-90 years of age) during incremental exercise tests. Subjects were categorized according to each individual's primary sport: speed-power athletes, endurance athletes, or untrained individuals. Gas exchange threshold was defined as the

point at which carbon dioxide concentration in the blood ($\dot{V}CO_2$) increased disproportionately to oxygen concentration ($\dot{V}O_2$), and the slope of the $\dot{V}CO_2$ vs $\dot{V}O_2$ curve was greater than 1.0. The researchers found that 80-year-old endurance runners or speed-power athletes were capable of maintaining a higher percentage of $\dot{V}O_{2max}$ at the GET than 20-year-old untrained control subjects.

Another aspect of the inherent aging process is the degradation of strength, power, and neuromuscular response, however it has been established that strength training slows atrophy and maintains (or increases) strength in older, untrained individuals (Brooks et al. 2005; Kragstrup et al. 2011; Louis et al. 2012). Similarly, Tarpenning and colleagues (2004) suggested the same to be true for Masters-level endurance athletes based on a study of 107 Masters-level distance runners (40-88 years of age). The researchers assessed maximal strength during a leg extension test for all subjects in addition to fiber typing muscle biopsies from 30 of the subjects. It was found that endurance running throughout life was associated with a reduced rate of atrophy in leg extensor muscles. Maximal voluntary contraction (MVC) torque of the leg extensor muscles peaked around age 30, was maintained through the age of 50, and dramatically declined at a rate of 12-15% per decade thereafter (Tarpenning et al. 2004). Conversely, there were no significant changes observed in leg strength or muscle fiber type until age 70. It was theorized that the 20-year age difference in leg strength and muscle fiber degradation was due to persistent endurance training as Masters athletes aged (Tarpenning et al. 2004). Although endurance training may not increase strength or muscle hypertrophy in Masters

athletes, it may prevent the early decline of these parameters (Brooks et al. 2005; Tarpenning et al. 2004).

Characterization of Duration, Frequency, and Intensity

Due to the flexible nature of individualized training programs designed for endurance athletes, it has been very difficult for researchers to implement longitudinal experimental designs aimed at finding an optimal training distribution (Seiler 2010). Moreover, well-trained athletes are often reluctant to alter successful training plans for the sake of research (Seiler and Tønnessen, 2009). Because of this, many researchers have performed observational studies and/or post hoc analyses on the training practices of successful endurance competitors in hopes of determining the optimal distribution (Nimmerichter et al. 2011; Seiler and Kjerland 2006).

Volume, intensity, and frequency are the most critical components involved in determining total training load (Achten and Jeukendrup 2003; Jeukendrup and Van Diemen 1998; Nimmerichter et al. 2011). However, the importance of each variable and the optimal distributions of each component are still under debate (Seiler and Tønnessen 2009; Nimmerichter et al. 2011). While both the frequency of exercise training and the duration of each exercise bout are easy to control and monitor quantitatively, it is more difficult to quantify training intensity due to the multifaceted nature of the parameter.

Exercise physiologists have struggled to universally define the intensity of exercise (Jeukendrup and Van Diemen 1998). Speed, power, rate of perceived exertion (RPE), HR, VO₂, metabolic equivalents (METs), and energy expenditure (kcal) are just

a few of the variables researchers have used to characterize the intensity of an athlete's training. Although practical in a lab setting, many of these variables are extremely difficult, or impossible, to simultaneously measure on multiple individuals in the field (Jeukendrup and Van Diemen 1998). This is especially true when studying cross country skiing, where snow conditions, drafting, terrain, and course profiles play a major role in determining exercise intensity (Bilodeau et al. 1994; Buhl et al. 2001; Mognoni et al. 2001). However, VO_{2max} and/or threshold tests provide athletes and coaches with HR data corresponding to these physiological biomarkers. Training HR data can then be used to define exercise intensity as a percentage of HR at VO_{2max} (% VO_{2max}), lactate threshold (%LT), ventilatory threshold (%VT), and/or maximum heart rate (% HR_{max}) (Jeukendrup and Van Diemen 1998).

Although lactate accumulation is not the cause of muscle fatigue, it is a physiological biomarker that indicates the point at which the rate of lactate appearance in the blood stream is greater than the rate of disappearance into the peripheral musculature (Brooks et al. 2005). Lactate threshold typically refers to the intensity at which lactate first accumulates in the blood. Well-trained endurance athletes are able to sustain this intensity for longer periods of time than untrained individuals. The lactate turnpoint (also known as the second lactate threshold (LT_2)) is the point at which lactate accumulation and subsequent hydrogen ion (H^+) concentration begin to increase exponentially (Bassett and Howley 2000; Brooks et al. 2005; Neal et al. 2013). At this point, the blood becomes more acidic and the body is no longer able to perform normal physiological responses at the cellular level.

Ventilatory threshold, the point at which the ventilatory equivalent of oxygen ($VE \cdot VO_2^{-1}$) increases without a concurrent increase in the ventilatory equivalent of carbon dioxide ($VE \cdot VCO_2^{-1}$), is another common physiological biomarker used to determine exercise intensity (Esteve-Lanao et al. 2005; Seiler and Kjerland 2006). If exercise intensity continues to increase past VT, the next physiological biomarker observed is the respiratory compensation threshold (RCT) or second ventilatory threshold (VT_2). This is the point at which increases in $VE \cdot VO_2^{-1}$ are accompanied by simultaneous increases in $VE \cdot VCO_2^{-1}$ (Esteve-Lanao et al. 2005; Seiler and Kjerland 2006).

Despite the fact that LT_1 and VT are not causal events, VT and the RCT tend to occur at approximately the same point as LT_1 and LT_2 , respectively (Neary et al. 1985). Therefore, heart rates at both the LT_1 and VT cut-points are often used as markers for low (below VT/ LT_1), moderate (above VT/ LT_1 but below the RCT/ LT_2), and high (above RCT/ LT_2) intensity exercise (Jeukendrup and Van Diemen 1998; Seiler and Kjerland 2006).

Distribution of Training Volume and Intensity

Nimmerichter et al. (2011) studied the exercise intensity and power output of 11 nationally and internationally competitive cyclists over 11 months. The majority of the cyclists implemented a two-part periodization model that consisted of two macrocycles, each with specific preparatory, pre-competition, and competition phases. For this study, seven intensity zones were defined by percentages of functional threshold power (FTP) at the RCT (Low Intensity: zone 1 < 50% FTP and zone 2 = 50-70% FTP; Moderate

Intensity: zone 3 = 71-85% FTP, zone 4 = 86-105% FTP, and zone 5 = 106-125% FTP; High Intensity: zone 6 = 126-170% FTP and zone 7 > 170% FTP). In addition, HR zones were determined from a graded exercise test (GXT) relating power output to HR. Over the course of the 11-month season, the researchers found that these elite cyclists spent approximately 73% of their training time at low intensity, 22% at moderate intensity, and only 5% at high intensity. Although these athletes were not following a typical polarized model of training, the majority of their time exercising (73%) was still spent at lower intensities.

Similarly, Seiler and Kjerland (2006) conducted a study classifying the training distribution for 12 nationally competitive junior cross country skiers. Three training zones were determined from breath-by-breath analysis of a $\text{VO}_{2\text{max}}$ test conducted on a treadmill to volitional exhaustion. Ventilatory threshold (VT_1), RCT (VT_2), and their associated HRs were used to define three training zones (HRs < HR at VT_1 , VT_1 < HR < VT_2 , and HRs > VT_2 for zones 1-3, respectively). Using the total time-in-zone method (defined as the actual time spent training at HRs associated within zones 1-3), the athletes spent 91% of training time below VT_1 , 6.4% between VT_1 and VT_2 , and only 2.6% above VT_2 . The researchers also used a session-goal approach for analyzing HR data. This method accounted for the potential lag in HR and/or underestimation of physiological exertion that occurs when athletes perform interval training or threshold work, which is typically shorter in duration but higher in overall physiological load. Session-goal analysis was shown to be a better predictor of average peak oxygen consumption than HR alone. Using this technique, the researchers found that the subjects spent $75 \pm 3\%$, $8 \pm$

3%, and $17 \pm 3\%$ (mean \pm standard deviation, $M \pm SD$) training in zones 1-3, respectively. These results were analogous to the periodized approach in use by many elite endurance athletes.

In a similar study on Masters-level triathletes (43 ± 3 years of age; $M \pm SD$), researchers used LT_1 and LT_2 to demarcate three intensity training zones. Neal et al. (2011) found that these athletes spent $69 \pm 9\%$ ($M \pm SD$) of total training time below their LT_1 (zone 1), $25 \pm 8\%$ between LT_1 and LT_2 (zone 2), and $6 \pm 2\%$ above LT_2 (zone 3). These results were consistent with the findings of Nimmerichter et al. (2011) in that both groups of athletes spent a majority of their training time at low intensities, some training time at moderate intensities, and very little training time at high intensities. Because the session-goal approach was not used during this study, the researchers may have underestimated the actual physiological load associated with short-duration, high-intensity training.

The distribution of training volume and intensity has also been characterized by macrocycles within a larger periodized training program (Enoksen et al. 2011; Guellich et al. 2009; Neal et al. 2011; Zapico et al. 2007). Cyclic periodization of training based off the athlete's competition schedule allows coaches and athletes to maximize training volume and intensity, minimize the risk of overtraining and/or injuries, and peak (maximize performance) during times of competition (Issurin 2010; Seiler 2010). Neal and colleagues (2011) found that there was a significant increase in absolute training time spent in zone 1 from periods A to B and a significant decrease in relative training time spent in zone 2 from periods A to C (where periods A, B, and C were 4-6, 2-4, and 0-2

months prior to the Ironman competition, respectively). Moreover, there was a general trend for total training volume to decrease from periods B to C despite a slight increase in absolute training time spent in zone 3 (Neal et al. 2011).

In a longitudinal study on 14 elite male cyclists (age < 23 years), HR was utilized to monitor each subject's volume and intensity over the course of two distinct training mesocycles: the winter mesocycle (November to February) and the spring mesocycle (February to June) (Zapico et al. 2007). These seasons were designed to correspond with the start of the training season in November, the decrease in high volume training and subsequent shift to higher intensity training in February, and the beginning of competition season in June. Training intensity was split into three training zones demarcated by HR corresponding to VT and RCT. The subjects recorded $77.7\pm 0.3\%$, $19.7\pm 0.6\%$, and $2.4\pm 0.3\%$ of their total winter training time in zones 1, 2, and 3, respectively. However, during the spring mesocycle the intensity of training shifted with subjects spending $69.9\pm 0.5\%$, $22.1\pm 0.4\%$, and $8.1\pm 0.2\%$ in zones 1, 2, and 3, respectively. While there was no significant difference in the percentage of time spent training in zone 2 between seasons, there was a significant decrease in percentage of time spent in zone 1 and a subsequent increase in percentage of time spent in zone 3 from winter to spring (Zapico et al. 2007).

Training Distribution and Race Performance

It has been suggested that the amount of time athletes spend training at low intensities correlates to improved race performance during endurance competition

(Esteve-Lanao et al. 2007; Esteve-Lanao et al. 2005; Guellich et al. 2009). Because competitive endurance athletes are often reluctant to change training for experimental purposes, the majority of relevant literature comes from observational studies (Seiler and Tønnessen 2009). Overall, elite and sub-elite endurance athletes tend to perform the majority of their training below LT and/or VT (Robinson et al. 1991; Mujika et al. 1995; Billat et al. 2001; Esteve-Lanao et al. 2005; Guellich et al. 2009). Assuming that these athletes have achieved success primarily due to training practices, researchers have suggested a correlation between low-intensity endurance training and race performance (Seiler and Tønnessen 2009).

In one of the few experimental studies conducted on this topic, researchers found that a low-intensity training program was significantly more effective at improving race performance than a moderate-intensity training program (Esteve-Lanao et al. 2007). Over the five months preceding competition season, 12 sub-elite endurance runners participated in either a low-intensity (subthreshold) or moderate-intensity (between thresholds) training program. The low-intensity group performed $80.5 \pm 1.5\%$ of training time below VT and $11.8 \pm 2.0\%$ of training time between the VT and RCT. Conversely, the moderate-intensity group performed $66.8 \pm 1.1\%$ of training time below VT and $24.7 \pm 1.5\%$ of training time between the VT and RCT. Both groups performed similar percentages of time training above the RCT. While both groups improved performance as a result of training, the low-intensity group saw greater improvements overall (Esteve-Lanao et al. 2007).

Telemetry-Based Heart Rate Monitoring

While a parameter such as speed may be an appropriate measurement of intensity for lap swimmers or track runners, it is less useful when trying to measure the intensity of an athlete swimming against a current or trail running on varied terrain (Jeukendrup and Van Diemen 1998). In the latter situations, measuring speed alone may not indicate the actual physiological stress on the individual. Therefore, intensity is ideally defined as a direct measurement of the amount of energy (hydrolyzed ATP) being expended as mechanical energy in order to perform a specific task over time (kJ/min) (Jeukendrup and Van Diemen 1998). While indirect calorimetry is measureable in a laboratory setting, it becomes much more complex, and often impossible, in the field. Jeukendrup and Van Diemen (1998) therefore suggested that intensity should be measured by HR response, a parameter closely related to energy expenditure, yet simple enough to use during almost any physical activity (PA).

Many researchers have characterized intensity based on HR response during bouts of PA (Kennedy and Bell 1996; Neumayr et al. 2003; Nimmerichter et al. 2011, Seiler and Kjerland 2006). While HR training zones are ideally determined by physiological cut-points such as VT, RCT, LT₁, and LT₂, the majority of recreational (as well as many competitive) athletes do not have access to these types of tests. The cost and time necessary to test a large group of individuals is often a barrier for researchers, coaches, and fitness professionals (Achten and Jeukendrup 2003; Jeukendrup and Van Diemen 1998). Moreover, the tests needed to accurately determine LT, VT, HR_{max}, and VO_{2max} are physically demanding, requiring the subject to work to the point of exhaustion. Many

athletes are uninterested in this form of testing due to the cost and demanding nature of the test protocols, but they are still interested in calculating HR zones to help monitor their training. Therefore, it was necessary to define a means by which HR zones can be determined for large groups of athletes, in the field, without having to perform maximal exercise testing (Achten and Jeukendrup 2003; Jeukendrup and Van Diemen 1998; Tanaka et al. 2001).

It is important to note that there are some limitations to using HR as a means of classifying intensity. Cardiac drift tends to occur in most individuals during long periods of exercise (Jeukendrup and Van Diemen 1998). This physiological phenomenon is characterized by an increase in HR despite a steady external work rate. In studies by Kindermann et al. (1979) and Mognoni et al. (1990), 20-60 minutes of exercise caused HR to drift upwards by as much as 20 beats per minute (bpm) despite a constant work output. Additionally, the researchers observed steady or decreasing plasma concentrations during this same period, indicating that while the external physiological load did not change, the heart muscle had to work harder to maintain its output.

A second limitation is that HR response tends to lag behind instantaneous increases in work output, especially during short duration, high intensity bouts of exercise (e.g., intervals, threshold repeats, sprints, etc.) (Achten and Jeukendrup 2003; Nimmerichter et al. 2011). For this reason, Seiler and Kjerland (2006) used the session-goal method when analyzing HR data. The researchers found that this method more accurately represented the lactate measurements, average peak oxygen consumption, and RPE over the course of the exercise bout. Despite the limitations, HR response during

exercise is an effective and practical method for measuring intensity on a large number of subjects over an extended period of time (Achten and Jeukendrup 2003; Jeukendrup and Van Diemen 1998; Kennedy and Bell 1996; Seiler and Kjerland 2006; Seiler and Tønnessen 2009; Tanaka et al. 2001).

Age-Predicted Maximum Heart Rate

Calculating age-predicted maximum heart rate (APMHR) is a common method of determining HR_{max} when a maximal exercise test is not practical. The traditional equation ($APMHR = 220 - \text{age}$) is often used in health fitness settings, hospitals, and among populations which may be reluctant or unable to perform maximal testing (Tanaka et al. 2001). However, this equation has a margin of error that tends to overestimate HR_{max} for individuals less than 40 years of age and underestimate HR_{max} for individuals over 40. Therefore, Tanaka et al. (2001) conducted a meta-analytical study in order to generate a more accurate equation for individuals over 40 years of age. After controlling for differences in test protocol, the researchers found that, independent of physical fitness or gender, age was a significant predictor of HR. Moreover, they found that the traditional equation used to predict maximum HR consistently underestimated the HR_{max} of individuals over age 40. For instance, the traditional equation has a standard deviation of approximately 10 bpm at age 70, which could underestimate HR_{max} by more than 20 bpm. Furthermore, they determined that an alternative equation, $APMHR = 208 - (0.7 \cdot \text{age})$, more accurately estimated HR_{max} for older adults (> 40 years old). Upon experimental verification, the researchers found that although HR_{max} did vary

significantly within age groups ($SD \pm 7-11$ bpm), there remained an inverse relationship between age and HR_{max} and the regression equation from the lab testing was almost identical to the results of the meta-analysis.

In a subsequent study conducted by Faff et al. (2007), 1,589 male and 1,180 female national caliber athletes (13-32 years of age) performed maximal HR testing on various kayak, rowing, treadmill, cycle, and/or ski ergometers based upon the athlete's primary sport. The measured HR_{max} across subjects was 193.1 ± 8.3 bpm ($HR_{max} \pm SD$). Similar to Tanaka et al., the researchers found that the traditional regression equation ($APMHR = 220 - \text{age}$) routinely over-predicted HR_{max} in this population, with a difference between the measured and predicted mean HR_{max} values (MD) being -7.6 ± 7.8 bpm (MD \pm SD) and a standard error of estimate (SEE) of ± 3.4 bpm. The regression equation found in this study, $APMHR = 208.5 - (0.8 \cdot \text{age})$, had a similar SD but a distinctly lower difference between actual and estimated HR_{max} values (0.0 ± 7.8) as well as a lower SEE of ± 2.7 bpm. Moreover, the total error (TE) for the traditional $220 - \text{age}$ equation was greater than the TE for the adjusted $208.5 - (0.8 \cdot \text{age})$ equation (± 10.9 and ± 7.8 bpm, respectively). Although this study was not conducted on Masters athletes, it builds upon the results of Tanaka et al. (2001), suggesting that a modified equation may be preferable, particularly for endurance athletes.

Summary

While some inherent aging factors may influence race performance outcomes in Masters-level skiers, researchers have shown that endurance training throughout life can

help mitigate these effects (Bassett and Howley 2000; Brooks et al. 2005; Hoff et al. 1999; Holloszy 2001; Kusy et al. 2012; Leyk et al. 2007). Training can be characterized by volume and frequency (determined from the regular recording of exercise bouts in a training log), as well as intensity, which can be determined based upon a variety of factors, including exercise HR response.

While HR training zones are ideally determined by physiological cut-points such as VT and RCT or LT_1 and LT_2 during a sport-specific graded exercise test, there are many challenges associated with administering these tests to large numbers of Masters athletes across a four state region (e.g., time, cost, resources, ability to rollerski on a treadmill, etc.). Therefore, using APMHR as the reference point for calculating HR training zones is a practical way of characterizing exercise training intensity within this population.

Lastly, in order to better understand the training practices of Masters-level skiers, training volume and intensity must be evaluated both within and between training periods preceding competition. Moreover, it is crucial to determine if there is a correlation between these training metrics and race performances of these same athletes.

CHAPTER THREE

DISTRIBUTION OF SEASONAL TRAINING INTENSITY
IN COMPETITIVE MASTERS-LEVEL
CROSS COUNTRY SKIERS

Contribution of Authors and Co-Authors

Manuscript in Chapter 3

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Contributions: Conceived study design, assisted with data analysis, discussed results and implications, and was primary editor of the manuscript at all stages.

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ABSTRACT

Professionals have long debated the optimal distribution of training volume and intensity necessary for improved performance by endurance athletes. Although researchers have studied the training distributions of high-level cross country (XC) skiers, the unique population of Masters-level XC skiers has been largely overlooked. Therefore, the primary purpose of this study was to characterize the changes in Masters-level skiers' training volume and intensity from the fall to mid-winter seasons using telemetry-based heart rate (HR) monitoring. The secondary purpose was to determine the relationship between winter training variables and race speed within the same population. Fifty-six Masters-level skiers volunteered to don a HR monitor and utilize a training log to record all bouts of physical activity over two 14+ day periods designed to correspond with the preparatory (fall) and pre-competition (mid-winter) seasons. After the mid-winter collection period, the same subjects recorded HR data while competing in a 34.4 km ski race. All HR data were downloaded to a computer and summarized by absolute training time (T, min) and relative time (%T) spent within six HR zones (Z) which were calculated as percentages of age-predicted maximum HR (APMHR). Training variables were compared using two-factor and three-factor multivariate repeated measures ANOVAs, whereas winter training variables and race HR variables were correlated with race speed using the Pearson product-moment correlation. Only 13 men (Mean±SD: 62±5 yrs.) and 15 women (50±5 yrs.) completed all of the study requirements. From the fall to winter seasons, weekly training volume was maintained (Mean±SE: 515.7±24.2 vs. 514.8±31.7 min/week, respectively), but average training HR significantly increased (117±2 vs. 123±2 bpm, respectively). Moreover, there was a significant decrease in the %T spent training <70% of APMHR and a significant increase in the %T spent training ≥70% from the fall to winter seasons (53.0±3.6% vs. 40.2±3.1% and 47.0±3.6% vs. 59.8±3.1%, respectively). Additionally, the skiers' distribution of training intensity within each season tended to follow a threshold based model, as opposed to the polarized model followed by high-level endurance athletes. While characterizing these training practices helps build the knowledge base necessary for improved coaching of this population, further observational and experimental research is warranted.

Introduction

Volume, intensity, and frequency are all critical components involved in the development and execution of endurance training programs (Achten and Jeukendrup 2003; Jeukendrup and Van Diemen 1998; Nimmerichter et al. 2011). While both the frequency of training and the duration of each exercise bout are easy to monitor quantitatively, it is more difficult to quantify training intensity due to the multifaceted nature of the parameter.

Intensity is ideally defined as a direct measurement of the amount of energy (hydrolyzed ATP) being expended as mechanical energy in order to perform a specific task over time (kJ/min) (Jeukendrup and Van Diemen 1998). While indirect calorimetry is measureable in a laboratory setting, it becomes much more complex, and often impossible, in the field. This is especially true when studying a sport such as cross country skiing where snow conditions, drafting, terrain, and course profiles play a major role in determining exercise intensity (Bilodeau et al. 1994; Buhl et al. 2001; Mognoni et al. 2001). However, physiological biomarkers, such as maximal oxygen uptake (VO_{2max}), ventilatory threshold (VT), respiratory compensation point (RCT), lactate threshold (LT_1), lactate turnpoint (LT_2), and maximum heart rate (HR_{max}), provide athletes and coaches with corresponding HR data which can then be used to define relative exercise intensity (Esteve-Lanao et al. 2005, Jeukendrup and Van Diemen 1998, Seiler 2010, Seiler and Kjerland 2006). However, in the absence of these physiological biomarkers, Jeukendrup and Van Diemen (1998) suggested that intensity could be determined from

HR response, a parameter closely related to energy expenditure yet simple enough to use during almost any physical activity (PA).

The distribution of training volume and intensity necessary for optimal performance among endurance athletes has been an area of continuous debate (Seiler and Kjerland 2006). Because competitive endurance athletes are often reluctant to change training for experimental purposes, the majority of relevant literature comes from observational studies (Seiler and Tønnessen 2009). While there is a great deal of research available on the benefits of untrained subjects exercising primarily at threshold (i.e., the threshold-training model) (Denis et al. 1984; Gaskill et al. 2001; Londeree 1997), a polarized-training model is more popular among elite athletes (Enoksen et al. 2011; Neal et al. 2013; Seiler and Kjerland 2006; Steinacker et al. 1998). Contrary to the threshold-training model, polarized training involves the vast majority of training time (> 75%) spent below the athlete's LT_1 or VT, with the remaining time spent distinctly above LT_2 or RCT, respectively (Seiler and Kjerland 2006).

Seiler and Kjerland (2006) collected HR data from 12 nationally competitive Norwegian junior skiers over 32 days. Heart rate data were divided into three training intensity zones demarcated by each subject's VT and RCT. The athletes' training followed a polarized training model, during which they performed $75 \pm 3\%$ of their training sessions below VT and $17 \pm 4\%$ of training above their RCT. The same physiological cut-points were used in a similar six-month macrocycle study of sub-elite endurance runners (Esteve-Lanao et al. 2005). Although the sub-elite runners did spend the majority of their training time below VT (71%), they spent more time training

between VT and RCT (21%), and less time training above their RCT (8%) when compared to the junior skiers (Esteve-Lanao et al. 2005).

Both volume and intensity can be calculated over the course of a single interval session, a week, an entire season, or multiple years during an athlete's career. Often, training plans are periodized to divide the season into subunits (e.g., preparatory, competition, and transition phases), each with their own specific training goals (Issurin 2010; Seiler 2010). Cyclic periodization of training based on the athlete's competition schedule allows coaches and athletes to maximize training volume and intensity, minimize the risk of overtraining and/or injuries, and peak (maximize performance) during times of competition (Issurin 2010; Seiler 2010).

In a longitudinal study on 14 elite male cyclists (age < 23 years) HR data were used to monitor intensity over the course of two distinct training mesocycles: winter (November to February) and spring (February to June) (Zapico et al. 2007). These seasons were designed to correspond with the start of the preparatory season in November, the decrease in high volume training and subsequent shift to higher intensity training in February, and the beginning of the competition season in June. The subjects recorded $77.7 \pm 0.3\%$, $19.7 \pm 0.6\%$, and $2.4 \pm 0.3\%$ of their total winter training time in zones 1 (below VT), 2 (between VT and RCT), and 3 (above RCT), respectively. During the spring mesocycle, training intensity shifted to subjects spending $69.9 \pm 0.5\%$, $22.1 \pm 0.4\%$, and $8.1 \pm 0.2\%$ in zones 1, 2, and 3, respectively. While there was no significant difference in the percentage of time spent training in zone 2 between seasons, there was a significant decrease in the percentage of time spent in zone 1 and a

subsequent increase in the percentage of time spent in zone 3 from winter to spring (Zapico et al. 2007).

It has been suggested that the amount of time athletes spend training at low intensities correlates to improved race performance during endurance competition (Esteve-Lanao et al. 2007; Esteve-Lanao et al. 2005; Guellich et al. 2009). Overall, elite and sub-elite endurance athletes tend to perform the majority of their training below LT and/or VT (Billat et al. 2001; Esteve-Lanao et al. 2005; Guellich et al. 2009; Mujika et al. 1995; Robinson et al. 1991). Assuming that these athletes have achieved success primarily due to training practices, researchers have suggested a positive correlation between the volume of low-intensity endurance training and race performance (Seiler and Tønnessen 2009).

While many researchers have studied elite, junior, and recreational skiers, the unique population of competitive Masters-level cross country skiers has been largely overlooked in the research literature (Fabre et al. 2008; Hoff et al. 1999; Sandbakk et al. 2011; Seiler and Kjerland 2006; Vergés et al. 2003). In the 2012 American Birkebeiner, the largest cross country ski race in North America and the fourth largest cross country ski race in the world, 82.5% of the 7,776 finishers were categorized as Masters-level skiers (American Birkebeiner Ski Foundation 2012). Despite the large number of competitive Masters-level cross country skiers, there has been little research conducted on how these individuals currently train.

Therefore, the primary purpose of this study was to characterize changes in training volume and intensity between the fall and winter training seasons in competitive

Masters-level cross country skiers using telemetry-based heart rate (HR) monitoring. The secondary purpose of this study was to determine the relationship between winter training volume, intensity, and 2014 Boulder Mountain Tour (BMT) race speed within the same population of skiers. It was hypothesized that there would be an increase in exercise intensity and a decrease in training volume between the fall and mid-winter collection periods. Additionally, it was hypothesized that there would be a positive correlation between mid-winter training intensity and average race speed during the 2014 Boulder Mountain Tour (BMT).

Methodology

Subject Recruitment

The recruitment of competitive Masters-level cross country skiers (40-73 years of age) took place in four centralized locations: Sun Valley, Idaho; Driggs, Idaho; Bozeman, Montana; and Park City, Utah. All skiers were planning to compete in the 2014 BMT 34.4 km skate ski race and considered cross country skiing their primary winter sport. At the time of recruitment, all subjects were training for the upcoming ski season and had participated in at least one prior long-distance (≥ 20 km) cross country ski race.

Volunteers attended an informational session (in-person or online) designed to inform them of the study design, collect anthropometric information (age, gender, height, weight, and birth date), and screen for possible health-related contraindications to participation. Upon acceptance into the study, subjects completed an informed consent document approved by Montana State University's (MSU) Institutional Review Board

(Appendix A). Lastly, subjects were required to participate in a standardized heart rate monitor (HRM) and training log tutorial which ensured all participants were provided with the same instructions prior to data collection.

Study Design

This study evaluated the change in training frequency, duration, and intensity of Masters-level cross country skiers over the course of two separate collection periods (fall and winter) using telemetry-based HRM systems. The data collection periods were designed to coincide with the preseason (preparatory) mesocycle and the pre-competition mesocycle, respectively (Rusko 2003).

Fall data collection occurred on a rolling basis from July 29th, 2013 – November 13th, 2013, with the majority of data collection occurring during September and October. Winter data collection occurred from January 2nd, 2014 – February 1st, 2014. Due to the observational nature of this study, subjects were asked to not change their training plan or workouts as a result of being monitored. Subjects maintained possession of the HRM equipment from the end of the second collection period through the day of the BMT (February 1st, 2014), when they used the HRM to collect HR data during the race, as well as during any warm-up period(s) preceding.

Data Collection Procedures

After attending the informational session, subjects used the HRM and training log to record all physical activity over 14 consecutive days. In the event a subject's schedule did not allow for 14 consecutive days of data collection, they were asked to record data

over two 7-day periods, representative of their typical fall training patterns. Physical activity was defined as anything longer than five minutes in duration beyond typical activities of daily living (e.g., shoveling snow was monitored and logged but vacuuming was not). Some activities were not conducive to wearing the HRM and/or chest strap due to poor conductivity (e.g., swimming, yoga, Pilates, etc.). In the event a subject was unable/forgot to wear their HRM, they were asked to log the activity and note the reason for noncompliance during that particular exercise bout. In order to ensure that HR data were collected in their entirety, subjects were asked to start the HRM before beginning each exercise bout and continue recording through the end of the workout (including any post-exercise stretching, cool-downs, physical therapy, etc.). Pre and post exercise data that were not needed for analysis were deleted during data reduction (see *Data Analysis*).

During the data collection periods, the researchers were available via phone and email to answer any questions that arose. Upon completion of the fall collection period, subjects returned the HRM equipment and training log (via mail or in person) to the MSU lab where the HRM data were uploaded and processed.

The HRM, chest strap, and a new training log were returned to the subjects approximately five weeks before the BMT. Exercise data collection began January 2nd, 2014 and continued through the end of the BMT ski race. The first 14 consecutive days of this collection period were analyzed as the subject's winter training data, thereby avoiding the tapering/recovery period immediately preceding BMT competition.

After the BMT race data were collected, subjects returned all equipment to the researchers, at which point the collected data were uploaded to a computer for analysis.

Upon successful completion of the study, subjects received copies of their HRM and training log data from both collection periods as well as their BMT HR data.

Instrumentation

Telemetry-Based Heart Rate Monitor. Polar RS400 training computers (wristwatches) (Polar Electro, Inc., Lake Success, NY, USA) and Polar H1 heart rate sensors were used to collect HR data in 5- and 15-second intervals during the fall and winter seasons, respectively. Setting the watch to collect HR data at 5-second intervals allowed for approximately 158 hrs of recording time. Changing the collection interval length to 15-seconds for the winter season ensured adequate memory availability (474 hrs) for five full weeks of data collection. Polar ProTrainer 5 software was used to upload and export raw HRM data to Microsoft Excel, where data were processed prior to analysis.

Exercise Training Log. An exercise training log, designed by MSU's Movement Science Laboratory (MSL) researchers, was supplied to each subject for use during the collection periods (Appendix B). For the purposes of this study, the training log information was used solely as a means of HR file verification. The only exception was subject response to "type of training" during the winter collection period. This information was used for secondary data analysis.

Data Processing

Training Heart Rate Data Screening. Individual HRM files were screened within the Polar ProTrainer 5 software to ensure that they matched the exercise bouts recorded in the subject's training log. Extraneous data were deleted and HR response curves were adjusted when blatant collection errors were observed within a HR file. Individual HR curves were evaluated exclusively by the primary researcher in order to maintain consistency both within and across subjects.

Criteria for data deletion included sudden and extreme increases in HR values which indicated HRM crosstalk, high-voltage electrical interference, or poor conductivity between the chest strap and subject. Moreover, HR data were only omitted if they did not match the corresponding training log entry, were physiologically improbable spikes in HR, or were HR values well above those observed during high-intensity interval training, threshold training, or race exercise bouts recorded by the same subject. Lastly, extended periods of time (greater than five minutes in duration) during which HR data were extremely low or "flat-lined" were excluded from the data analysis. Extremely low HR values referred to data that was more than 10 bpm below 50% of the subject's age-predicted maximum HR (APMHR) whereas "flat-line" data was defined as zero variation in HR data points over a period of time.

If there was any indecision regarding deletion, the HR data were left unedited. Heart rate files that were clearly recorded exercise bouts ($HR \geq 50\%$ APMHR and > 5 min in duration), but were not logged, were retained for data analysis. It was assumed

that these files were legitimate exercise bout recordings that the subject simply forgot to record in their training log.

All activities of daily living, as well as extremely low-intensity exercises, were excluded from data analysis. Activities excluded from analysis (regardless of whether or not they had been recorded) included: yard work, “casual/easy” walks, household chores, field work, and very low-intensity body awareness activities (e.g., yoga, meditation, physical therapy). The only exception to the aforementioned exclusions was when a subject clearly indicated the incorporation of added challenge (e.g., weights, uphill walking), thereby increasing the intensity of the exercise bout. Subjects who failed to collect HR data for $\geq 70\%$ of their total time logged (after excluded activities were removed) were dropped from the study due to insufficient HR data collection.

Training Heart Rate Data Processing. Raw HR data were exported to a spreadsheet program for weekly training volume and intensity analysis. Age-predicted maximum heart rate for each subject was calculated using the equation $HR_{\max} = 208 - (0.7 \cdot \text{age})$ (Tanaka et al. 2001) and percentages of each subject’s APMHR were used to demarcate six HR training zones (Z_x , where x = the training zone number): $Z_0 = HR < 50\%$ of APMHR; $Z_1 = 50\% \leq HR < 60\%$; $Z_2 = 60\% \leq HR < 70\%$; $Z_3 = 70\% \leq HR < 80\%$; $Z_4 = 80\% \leq HR < 90\%$; $Z_5 = HR \geq 90\%$. The following training intensity variables were summarized from the HRM data: mean exercise HR (HR_{avg} , bpm), mean HR as a percentage of APMHR ($\%HR_{\text{avg}} = [HR_{\text{avg}} / \text{APMHR}] \cdot 100$), maximum HR recorded (HR_{MaxR}), and the minimum HR recorded (HR_{MinR}).

Training volume variables summarized from the HRM and training log data included: the number of exercise bouts recorded on the HRM (N_{rec}), the number of bouts logged in the training diary per week (N_{log}), weekly training time recorded and logged (T_{rec} and T_{log} , respectively; min/week), weekly training time spent exercising in each HR training zone (TZ_x , where x = the training zone number; min/week), and the percentage of weekly training time spent in each HR training zone calculated as $\%TZ_x = (TZ_x / T_{\text{rec}}) \cdot 100$. All the aforementioned processes were then repeated for the data collected during the winter training period.

Winter data processing also included the analysis of each subject's "type of training", as recorded in the training logs. Subjects were asked to choose one of eight training types for each exercise bout: low-intensity recovery, long-distance, mixed-endurance, threshold, speed intervals, high-intensity intervals, resistance training, or other. Each exercise bout was individually reevaluated for validity by the primary researcher, thereby verifying that the training type selected matched the subject's HR curve, RPE, perceived training zones, and comments (e.g., all races were re-categorized as threshold training, regardless of their original classification). All "other" bouts were re-categorized into one of the remaining seven categories by the primary researcher. In the event a subject did not categorize an exercise bout, the primary researcher made an educated decision (based on the aforementioned criteria) regarding type of training categorization. Average weekly training time (min/week) and percentage of weekly training time per training category type were then calculated for each subject (TC_x and $\%TC_x$, respectively, where x = the category type).

The original type of training categories were next combined into three composite categories based on whether the type of training was typically performed below-threshold, at-threshold, or above-threshold intensity. Because normal threshold biomarkers (LT or VT) were not measured during this study, threshold intensity referred to exercise intensity that simulated an individual's race-pace for a set duration of time (usually >20 min). For competitive endurance athletes, the pace is often described as hard, yet attainable. As a reference point, subjects were told to compare threshold intensity to their race-pace during an endurance event > 10 km. Therefore, low-intensity recovery, long distance, and mixed endurance type of training categories were considered "below-threshold" intensity, whereas speed intervals, high-intensity intervals, and resistance training categories were considered "above-threshold" intensity.

Race Heart Rate Data Processing. Data analysis for the BMT race data included determination of each skier's mean race heart rate (BMT HR_{avg} ; bpm), mean race heart rate as a percentage of APMHR (BMT % HR_{avg}), maximum and minimum race HR (BMT HR_{MaxR} and BMT HR_{MinR} , respectively), race time as determined from official race results (BMT $_{RT}$; min), and race speed (BMT $_{SP}$; km/hr). Overall Boulder Mountain Tour HR variables were determined from the point at which the subjects HR reached a visual steady-state through the end of the race. The same HR variables were also evaluated using only the first 30 minutes of the subject's race (F30 HR_{avg} , F30 % HR_{avg} , F30 HR_{MaxR} , and F30 HR_{MinR} , respectively) and the last 30 minutes of their race (L30 HR_{avg} , L30 % HR_{avg} , L30 HR_{MaxR} , and L30 HR_{MinR} , respectively). All files were backed up on an external hard drive and coded to protect the subjects' confidentiality.

Statistical Analysis

Global summary variables representing training volume (N_{rec} , N_{log} , T_{rec} , T_{log}) and intensity (HR_{avg} , $\%HR_{\text{avg}}$, HR_{MaxR} , and HR_{MinR}) for both the fall and winter collection periods were compared using a two-factor (subject x season) multivariate repeated measures ANOVA. Training zone summary variables (TZ_x and $\%TZ_x$) for both fall and winter were compared using a three-factor (subject x season x [TZ_x , $\%TZ_x$]) multivariate repeated measures ANOVA with contrasts for comparing variables across seasons at the same training zone (e.g., TZ1 for the fall was only compared with TZ1 for the winter). The same analyses were performed with the modified training zone summary variables ($TZ012$, $TZ345$, $\%TZ012$, and $\%TZ345$), the seven winter “type of training” exercise bout categorization variables (TC_x and $\%TC_x$), and the combined exercise bout categorization variables (absolute and relative weekly time below-, at-, and above-threshold).

Finally, BMT HR_{avg} , $\%BMT HR_{\text{avg}}$, training volume variables, and training intensity variables (as described above) were correlated with BMT_{SP} using the Pearson product-moment correlation. Variables were summarized as mean \pm standard deviation ($M \pm SD$) or mean \pm standard error of the mean ($M \pm SEM$) for descriptive and comparative variables, respectively. All statistical analyses were evaluated at the 0.05 alpha-level using the statistical software Statistix (Version 10; Analytical Software, Tallahassee FL USA).

Results

Subjects

Fifty six subjects were recruited for the fall portion of the study, 31 men and 25 women (40-73 years of age). Only 28 (50%) of these subjects met the criteria for final data analysis while the other 28 dropped out, or were dropped, from the study. Nineteen subjects voluntarily withdrew from the study during the fall or winter seasons ($n = 8$ and $n = 11$, respectively) due to illness or injury ($n = 10$), an inability to complete the study requirements ($n = 7$), or other undisclosed reasons ($n = 2$). Subjects that failed to meet the 70% heart rate recording requirement ($n = 6$) during the fall or winter seasons, in addition to those who chose not to compete in the 2014 BMT skate ski race ($n = 3$), were also dropped from the study.

The remaining 13 men (Mean \pm SD: 55 \pm 8 yrs.; 23.6 \pm 1.7 kg/m²) and 15 women (56 \pm 8 yrs.; 20.8 \pm 1. kg/m²) resided and trained in Sun Valley, ID ($n = 13$), Bozeman, MT ($n = 6$), Salt Lake City/Park City, UT ($n = 6$), Pocatello, ID ($n = 2$), and Wilson, WY ($n = 1$). All subjects considered cross country skiing their primary winter sport and were self-described competitive Nordic ski racers. Additionally, all subjects had previous experience with long distance (≥ 20 km) cross country ski racing, with 26 of the subjects having competed in at least one previous BMT. Subjects were free of injury/illness preventing normal training practices and were not taking medications that could potentially have altered HR data.

Seasonal Distributions of Training Volume

The number of weekly exercise bouts recorded and logged during the fall and winter seasons were statistically similar ($P = 0.18$ and 0.17 , respectively) as were total weekly time recorded and logged between seasons ($P = 0.98$ and 0.42 , respectively) (Table 3.1.). There were no significant differences found when the data were subanalyzed by gender or age group. Therefore, all subsequent data analyses were applied to the entire subject sample.

Table 3.1. Total number of exercise bouts recorded (via HR monitor) and logged (in a training log) per week, as well as total weekly training time recorded and logged by competitive Master cross country skiers ($n=28$), by training season. Mean \pm SE, with ranges in parentheses.

	Number of Weekly Exercise Bouts Recorded	Number of Weekly Exercise Bouts Logged	Weekly Training Time Recorded (min)	Weekly Training Time Logged (min)	Weekly Training Time Recorded (hrs.)	Weekly Training Time Logged (hrs.)
Fall	6.6 \pm 0.4 (3.5-11.0)	7.8 \pm 0.5 (5.0-15.0)	515.7 \pm 24.2 (283.3-819.7)	591.5 \pm 28.9 (344.5-995.0)	8.6 \pm 0.4 (4.7-13.7)	9.9 \pm 0.5 (5.7-16.6)
Winter	6.1 \pm 0.4 (3.5-11.0)	7.3 \pm 0.4 (4.0-14.5)	514.8 \pm 31.7 (280.0-1007.6)	570.8 \pm 32.8 (377.5-1029.0)	8.6 \pm 0.5 (4.7-16.8)	9.5 \pm 0.5 (6.3-17.2)

Seasonal Distribution of Training Intensity

Average heart rate across all exercise bouts and training intensities, as well as %HR_{avg}, increased significantly from the fall to winter seasons ($P < 0.01$ and < 0.01 , respectively). However, maximum and minimum recorded HR were statistically similar between seasons ($P = 0.32$ and 0.47 , respectively) (Table 3.2).

Table 3.2. Mean HR_{avg} , HR_{MaxR} , HR_{MinR} , and HR_{avg} as a percentage of APMHR ($\%HR_{avg}$) of 28 competitive Master cross country skiers during the fall and winter training seasons. Mean \pm SE, with ranges in parentheses.

	HR_{avg}^* (bpm)	HR_{MaxR} (bpm)	HR_{MinR} (bpm)	$\%HR_{avg}^*$ (%)
Fall	117 \pm 2 (87-140)	167 \pm 2 (140-183)	60 \pm 1 (47-70)	68.9 \pm 1.2 (54.3-81.7)
Winter	123 \pm 2 (104-148)	169 \pm 2 (153-182)	61 \pm 2 (43-79)	72.7 \pm 1.1 (64.5-86.8)

* Denotes significant difference between seasons.

There were no significant differences between seasons when comparing weekly training time per zone across seasons (e.g., time in Z1 during the fall vs. time in Z1 during the winter) (Table 3.3). There was, however, a significant decrease in the percentage of training time spent in Z2 and a significant increase in the percentage of training time spent in Z4 from fall to winter ($P < 0.05$) (Table 3.4). Additionally, subjects recorded significantly less absolute and relative time in Z5 when compared to Z1, Z2, Z3, or Z4 during the fall season and significantly less absolute and relative training time in Z0 when compared to Z1, Z2, Z3, or Z4 during the winter ($P < 0.05$).

Table 3.3. The distribution of weekly training time spent exercising in six HR zones (TZ0 – TZ5) by competitive Masters-level cross country skiers ($n=28$). Training zone cut-points were as follows: Z0= $HR < 50\%$ of APMHR; Z1= $50\% \leq HR < 60\%$; Z2= $60\% \leq HR < 70\%$; Z3= $70\% \leq HR < 80\%$; Z4= $80\% \leq HR < 90\%$; Z5= $HR \geq 90\%$. Mean \pm SE by season, with ranges in parentheses.

	TZ0 (min)	TZ1 (min)	TZ2 (min)	TZ3 (min)	TZ4 (min)	TZ5 (min)
Fall	58.1 \pm 11.0* \times † (1.8-240.7)	98.6 \pm 11.2 (14.8-260.1)	121.1 \pm 8.2 (46.3-224.7)	111.4 \pm 9.2 (29.9-241.7)	87.5 \pm 12.0 (11.2-313.8)	38.9 \pm 6.9* \times †‡ (0.00-119.7)
Winter	45.6 \pm 8.7* \times †‡ (1.0-197.5)	83.7 \pm 11.9 (3.6-246.0)	91.9 \pm 11.1 (15.3-273.9)	116.5 \pm 8.5 (47.5-192.0)	118.0 \pm 7.6 (47.8-205.5)	59.1 \pm 10.0†‡ (0.1-191.5)

* Denotes significant difference from TZ1 within season.

\times Denotes significant difference from TZ2 within season.

† Denotes significant difference from TZ3 within season.

‡ Denotes significant difference from TZ4 within season.

Table 3.4. Percentage of weekly training time spent exercising in six HR zones (%TZ0 - %TZ5) by competitive Masters-level cross country skiers (n=28). Training zone cut-points were as follows: Z0=HR<50% of APMHR; Z1=50%≤HR<60%; Z2=60%≤HR<70%; Z3=70%≤HR<80%; Z4=80%≤HR<90%; Z5=HR≥90%. Mean±SE by season, with ranges in parentheses.

	%TZ0 (%)	%TZ1 (%)	%TZ2** (%)	%TZ3 (%)	%TZ4** (%)	%TZ5 (%)
Fall	10.5±1.7* ^z † (0.5-35.9)	18.7±1.6 (3.8-38.8)	23.7±1.4 (12.0-44.8)	21.8±1.4 (4.5-46.6)	17.2±2.1 (1.6-41.4)	8.0±1.5* ^z †‡
Winter	8.1±1.2* ^z †‡ (0.2-21.2)	15.2±1.4†‡ (0.8-33.3)	16.9±1.2‡ (3.3-30.4)	22.8±1.3 (10.4-37.4)	24.5±1.7 (9.0-44.5)	12.5±2.1†‡ (0.0-38.9)

** Denotes significant difference between seasons.

* Denotes significant difference from %TZ1 within season.

^z Denotes significant difference from %TZ2 within season.

† Denotes significant difference from %TZ3 within season.

‡ Denotes significant difference from %TZ4 within season.

Average weekly training time in Z3, Z4, and Z5 tended to increase from fall to winter, while time spent in Z0, Z1, and Z2 tended to decrease (Table 3.3). Although not significant at the 0.05 α -level, these trends led to a secondary analysis which grouped training zones above and below 70% of APMHR (Z012 = HR < 70% of APMHR; Z345 = HR ≥ 70% of APMHR). The cumulative amount of time (TZx) and percentage of time (%TZx) each subject spent training at < 70% APMHR and ≥ 70% APMHR (TZ012, %TZ012, TZ345, and %TZ345, respectively) were calculated as modified training zones. Combining training zones further emphasized the tendency for lower intensity training time (Z012) to decrease and higher intensity training time (Z345) to increase from fall to winter, despite remaining non-significant at the 0.05 α -level (Table 3.5). There was, however, a significant decrease in the percentage of training time spent in Z012 and a significant increase in the percentage of training time spent in Z345 from fall to winter (P < 0.05) (Table 3.6).

Table 3.5. The distribution of weekly training time spent exercising in combined HR zones TZ0+TZ1+TZ2 (TZ012) and TZ3+TZ4+TZ5 (TZ345) by competitive Master cross country skiers (n=28). Training zone cut-points were as follows: Z012=HR<70% of APMHR; Z345=HR≥70%. Mean±SE by season, with ranges in parentheses.

	TZ012 (min)	TZ345 (min)
Fall	277.8±26.1 (63.0-628.0)	237.9±22.2 (41.8-641.0)
Winter	221.2±28.2 (20.0-626.3)	293.6±14.6 (166.4-504.8)

Table 3.6. Percentage of weekly training time spent exercising in combined HR zones (%TZ012 and %TZ345) by competitive Masters-level cross country skiers (n=28). Training zone cut-points were as follows: Z012=HR<70% of APMHR; Z345=HR≥70%. Mean±SE by season, with ranges in parentheses.

	%TZ012* (%)	%TZ345* (%)
Fall	53.0±3.6 (16.3-94.0)	47.0±3.6 (6.3-83.7)
Winter	40.2±3.1 (4.3-62.3)	59.8±3.1 (37.7-95.7)

* Denotes significant difference between seasons.

Evaluation of winter exercise intensity using the type of training approach revealed significantly more weekly training time spent performing long-distance exercise than any other exercise type ($P < 0.05$) (Table 3.7). Subjects also spent significantly less time performing speed intervals when compared to low intensity recovery, long distance, or mixed endurance training ($P < 0.05$). In addition, when session-goal time was evaluated as a percentage of total training time, subjects spent a significantly smaller

percentage of time performing resistance training when compared to the relative time spent performing low intensity recovery, long distance, or mixed endurance training ($P < 0.05$) (Table 3.7).

Table 3.7. Weekly training time spent in type of training categories by competitive Masters-level cross country skiers during the winter season (n=28). Evaluation of each exercise's type of training was initially determined from the subject's training log and confirmed using the corresponding HR file. Mean \pm SE with ranges in parentheses.

	Low Intensity Recovery	Long Distance	Mixed Endurance	Threshold	Speed Intervals	High Intensity Intervals	Resistance Training
Weekly Training Time (min)	88.2 $\pm 16.9^{*\dagger}$ (0.0-383.1)	168.7 $\pm 23.9^\dagger$ (0.0-586.1)	82.8 $\pm 16.8^{*\dagger}$ (0-336.5)	70.6 $\pm 10.1^*$ (0.0-174.5)	15.3 $\pm 7.7^*$ (0.0-172.4)	61.9 $\pm 11.1^*$ (0.0-221.3)	27.3 $\pm 7.0^*$ (0-120.9)
Percentage of Training Time (%)	16.5 $\pm 2.3^{*\dagger\ddagger}$ (0.0-45.1)	32.0 $\pm 3.8^\dagger\ddagger$ (0.0-83.0)	16.9 $\pm 3.0^{*\dagger\ddagger}$ (0.0-48.3)	14.7 $\pm 2.3^{*\dagger}$ (0.0-41.0)	2.7 $\pm 1.2^*$ (0.0-28.6)	12.2 $\pm 2.1^*$ (0.0-40.2)	5.1 $\pm 1.4^*$ (0.0-26.4)

*Denotes significant difference from Long Distance.

\dagger Denotes significant difference from Speed Intervals.

\ddagger Denotes significant difference from Resistance Training.

When the original type of training categories were combined to form composite categories (below-, at-, and above-threshold intensity), subjects spent significantly more absolute and relative training time during the winter season performing activities in the below-threshold composite category ($P < 0.05$). The absolute and relative time spent in the at-threshold and above-threshold categories were statistically similar (Table 3.8).

Table 3.8. Absolute (min) and relative (%) weekly training time spent in composite type of training categories by competitive Masters-level cross country skiers during the winter season (n=28). Mean \pm SE with ranges in parentheses.

	Below-Threshold	At-Threshold	Above-Threshold
Weekly Training Time (min)	339.7 \pm 31.5* (68.5-812.6)	70.6 \pm 100.1 (0.0-174.5)	104.5 \pm 19.9 (0.0-421.5)
Percentage of Training Time (%)	65.3 \pm 4.0* (15.0-100.0)	14.7 \pm 2.3 (0.0-41.0)	20.0 \pm 3.4 (0.0-76.7)

*Denotes significant difference from at and above-threshold session-goals.

Boulder Mountain Tour Race Analysis

Boulder Mountain Tour race data are outlined in Table 3.9. Age significantly and negatively correlated to BMT race speed ($r = -0.56$; $P < 0.01$). Similarly, BMT HR_{avg} over the entire race, during the first 30 minutes, and during the last 30 minutes all significantly and positively correlated to race speed ($r = +0.59, +0.56, +0.61$, respectively; $P \leq 0.01$), but HR average as a percentage of APMHR (BMT % HR_{avg}) did not (Table 3.9).

Table 3.9. Boulder Mountain Tour average race time (RT), race speed (RS), race HR, and race HR as a percentage of age-predicted heart rate maximum (% HR_{avg}) for the total sample of competitive Masters cross country skiers, men vs. women, and younger vs. older. Mean \pm SD, with ranges in parentheses.

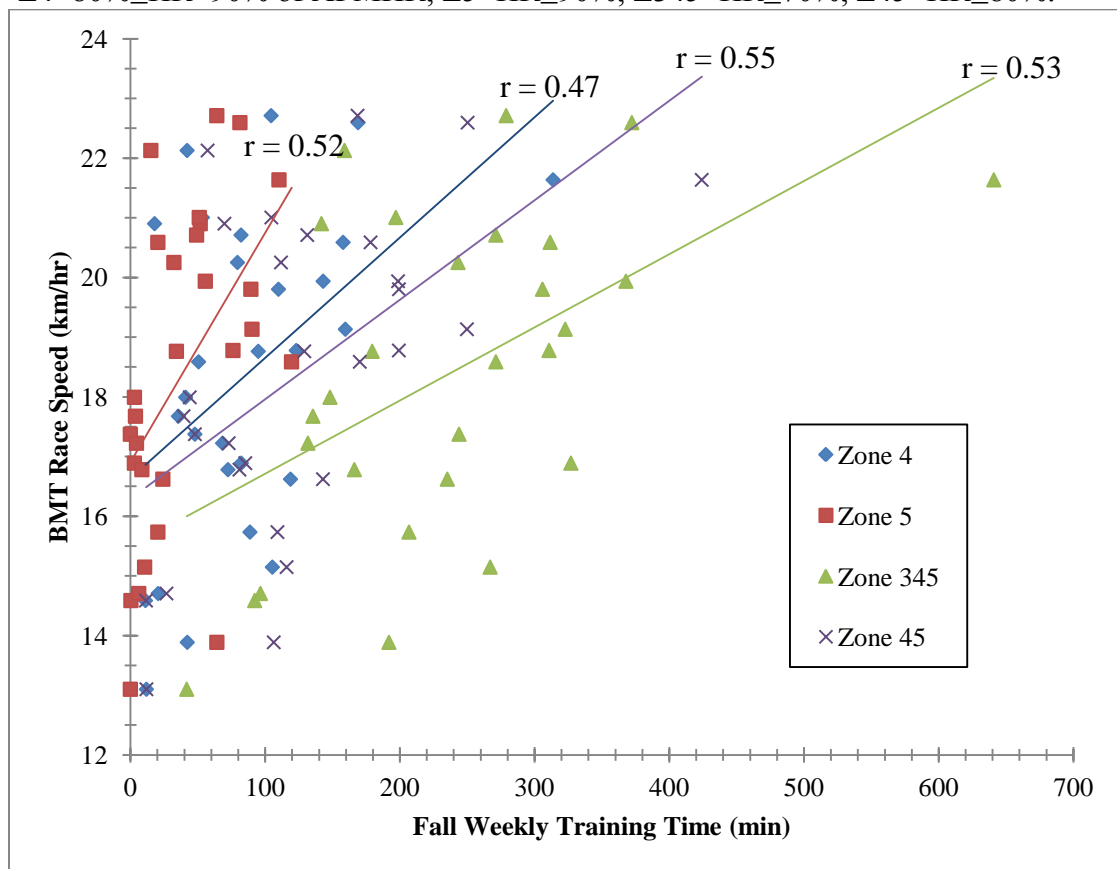
	All Subjects (n = 28)	Male (n = 13)	Female (n = 15)	Younger: ≤ 55 years (n = 15)	Older: > 55 years (n = 13)
BMT _{RT} (min)	114.7 \pm 18.0 (90.9-157.6)	108.2 \pm 17.1 (90.9-141.5)	120.4 \pm 17.4 (98.3-157.6)	108.0 \pm 12.1 (90.9-131.2)	122.5 \pm 20.9 (93.3-157.6)
BMT _{SP} (km/hr)	18.3 \pm 2.7 (13.1-22.6)	19.4 \pm 2.7 (14.5-22.6)	17.4 \pm 2.4 (13.1-20.9)	19.3 \pm 2.1 (15.7-22.6)	17.3 \pm 3.0 (13.1-22.1)
BMT HR_{avg} (bpm)	155 \pm 9* (134-172)	158 \pm 9 (145-172)	153 \pm 9 (134-168)	158 \pm 8 (142-169)	151 \pm 9 (134-172)
BMT % HR_{avg} (%)	91.7 \pm 4.6 (83.0-104.3)	93.2 \pm 4.7 (85.1-104.3)	90.3 \pm 4.1 (83.0-96.8)	91.5 \pm 3.9 (83.0-98.4)	91.9 \pm 5.4 (83.8-104.3)

*Denotes significant correlate to BMT race speed.

Fall Training Data and BMT Race Speed. Although the total weekly training time recorded on the HR monitors by subjects during the fall season did not correlate to BMT race speed, the time these athletes logged neared significance ($r = +0.36$, $P = 0.06$). Fall weekly training time spent in Z4, Z5, Z345, and Z45 significantly and positively correlated with BMT race speed ($r = +0.47, +0.52, +0.53$, and $+0.55$, respectively; $P \leq 0.01$) (Figure 3.1). The percentage of training time spent in Z4, Z5, Z345, and Z45 significantly and positively correlated with BMT race speed ($r = +0.38, +0.38, +0.41$, and

+0.44, respectively; $P \leq 0.05$). Conversely, the percentage of time spent in Z1, Z2, and Z012 significantly and negatively correlated with BMT race speed ($r = -0.45, -0.50,$ and $-0.41,$ respectively; $P \leq 0.03$).

Figure 3.1. Correlation between Boulder Mountain Tour race speed and weekly training time spent in various training zones during the fall season for competitive Master cross country skiers ($n=28$). Training zone (Z) cut-points were as follows: Z4= $80\% \leq HR < 90\%$ of APMHR; Z5= $HR \geq 90\%$; Z345= $HR \geq 70\%$; Z45= $HR \geq 80\%$.



Winter Training Data and BMT Race Speed. Recorded weekly training time during the winter seasons significantly and positively correlated with BMT race speed ($r = +0.42; P = 0.03$) (Figure 3.2). When the three outliers were removed from this analysis, the correlation markedly improved ($r = +0.63$) (Figure 3.3).

Figure 3.2. Correlation between Boulder Mountain Tour race speed and competitive Masters-level cross country skier's weekly training time during the winter season (n=28). Outlying data points are highlighted in red.

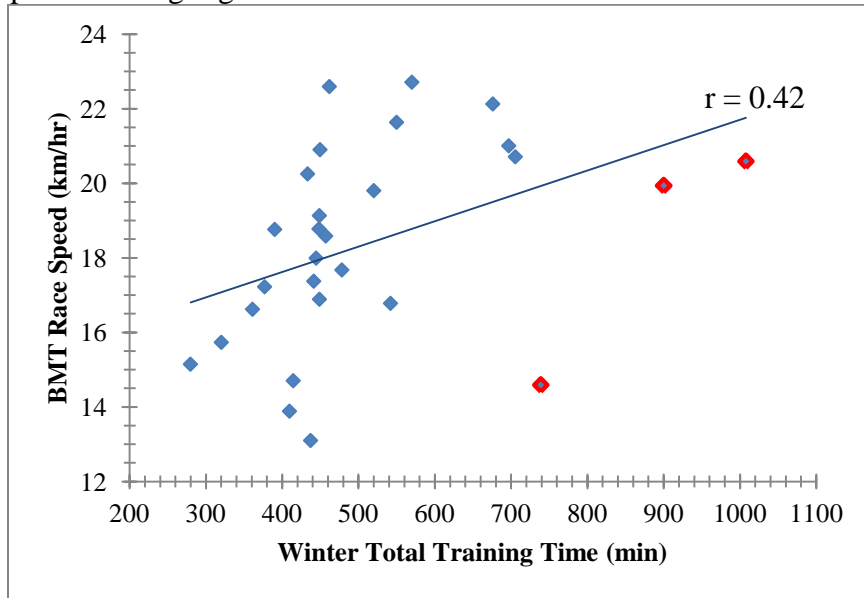
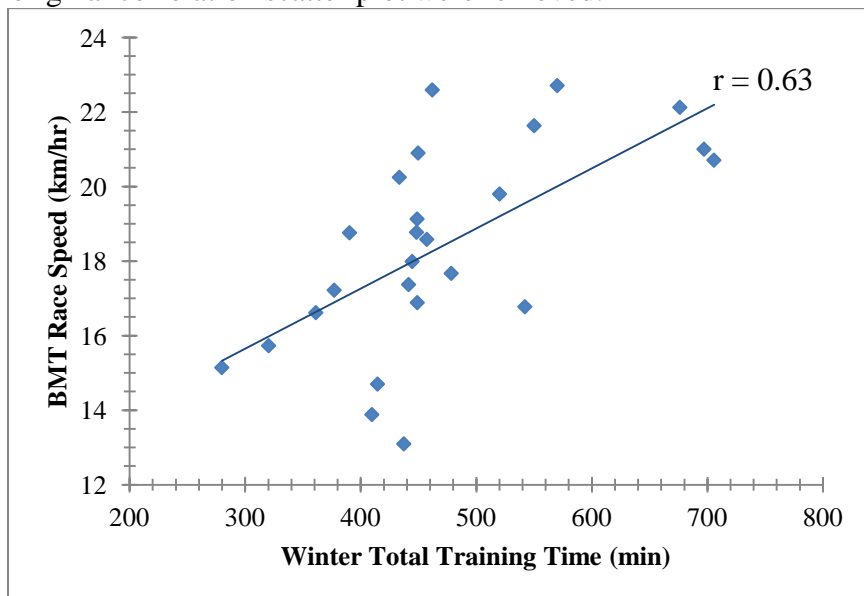
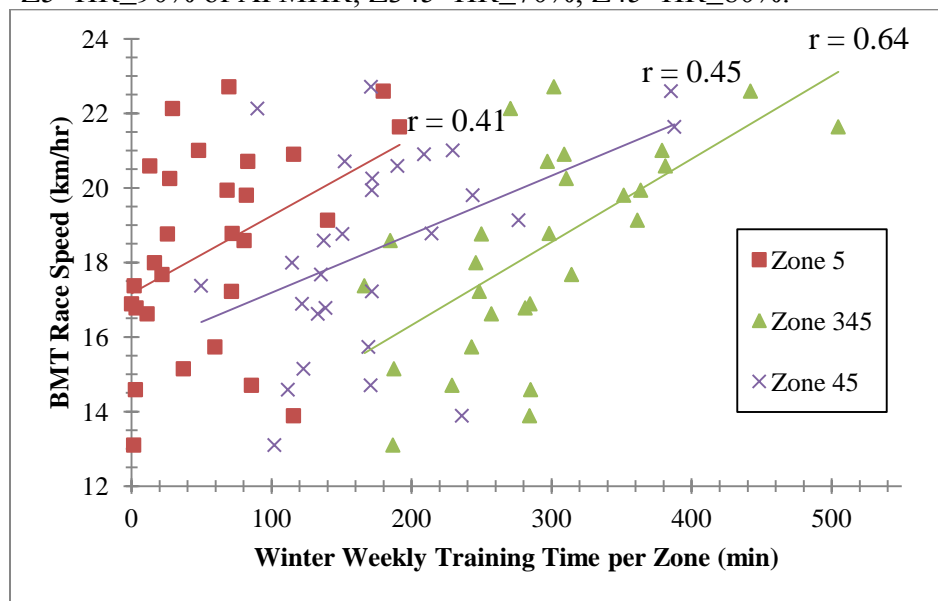


Figure 3.3. Correlation between Boulder Mountain Tour race speed and competitive Masters-level cross country skier's weekly training time during the winter season (n=25). Three outliers from original correlation scatter plot were removed.



Additionally, training time spent in Z5, Z45, and Z345 significantly and positively correlated to BMT race speed ($r = +0.41, +0.45, \text{ and } +0.64$ respectively; $P \leq 0.03$) (Figure 3.4). There were no significant correlations between percentage of weekly training time per zone (individual or combined) and BMT race speed. Moreover, the type of training categorizations (original or composite) did not correlate to BMT race speed.

Figure 3.4. Correlation between Boulder Mountain Tour race speed (km/hr) and competitive Masters-level cross country skiers weekly training time (min) spent in various training zones during the winter season ($n=28$). Training zone (Z) cut-points were as follows: Z5=HR \geq 90% of APMHR; Z345=HR \geq 70%; Z45=HR \geq 80%.



Discussion

To our knowledge, there has been no prior research conducted on the distribution of training of Masters-level cross country skiers beyond their physiological peak.

Therefore, the primary purpose of this study was to characterize the changes in training volume and intensity in competitive Masters-level cross country skiers between the fall

and mid-winter seasons. The secondary purpose of this study was to determine the relationship between mid-winter training intensity and racing speed. It was hypothesized that there would be an increase in exercise intensity and a decrease in training volume between the fall and mid-winter collection periods. Additionally, it was hypothesized that there would be a positive correlation between mid-winter training intensity and average race speed during the 2014 Boulder Mountain Tour (BMT).

Subjects

The subject retention rate for this sample of competitive Masters-level cross country skiers was 60.7%. Six additional subjects were dropped from the study after data screening because they failed to record $\geq 70\%$ of their logged training time, further decreasing the subject retention rate for data analysis to 50%. The subject retention rate of this study was similar to the 61% retention rate observed in a previous study on recreational Masters-level skiers (Ranta et al. 2013).

This 50% subject retention rate is extremely low when compared to the retention rates of other observational training distribution studies: 100%, 100%, and 91.7% retention rates observed by Esteve-Lanao et al. 2007, Guellich et al. 2009, and Seiler and Kjerland, 2006, respectively. However, it is important to note that all three of these observational studies were conducted within organized training groups as opposed to the present study, which was comprised of 56 individual athletes spread over a four-state region. Increased interaction between the subjects and researchers during the collection periods, in addition to constant reminders to record and log workouts from peers, may

have improved subject retention rates within the present study. Therefore, future studies may benefit from focusing on one Masters-level training group in a centralized location.

Additionally, it is important to note that many of the observational studies have been conducted with young (≤ 25 years) national and international, elite and sub-elite athletes as opposed to older, Masters-level athletes ≥ 40 years of age. Due to the inherent process of aging (specifically the stiffening of tendons, wearing of cartilage, and degradation of bone) older athletes are at higher risk for orthopedic injuries (Kallinen and Alén 1994; Maharam et al. 1999). Moreover, because it takes older individuals longer to understand and learn how to use computer software applications, such as the Polar RS400 training computer (wristwatch), future studies may increase subject retention by implementing a familiarization period, during which the athletes could record workouts and receive feedback from the researchers prior to actual data collection (Jones and Bayen 2006; Kelly and Charness 2007).

Training Volume

The fall and winter collection periods were designed to characterize Master-level skiers' training during the preparatory and pre-competition macrocycles, respectively. The average number of weekly training bouts logged during the fall and winter (7.8 and 7.3 bouts/wk., respectively) were very similar to the 7.7 bouts/wk. performed by well-trained junior skiers during their pre-competition season (Seiler and Kjerland 2006). Although the total training time per week was not reported by Seiler and Kjerland (2006), the total training times logged during the fall and winter seasons (591.5 and 570.8 min/wk., respectively) were comparable to the amount of time Master-level triathletes

trained during their preparatory and pre-competition seasons (660 and 594 min/wk., respectively) (Neal et al. 2011).

While the average time logged decreased from the fall to winter collection periods, the lower and upper bounds of the time logged increased slightly. When the average number of weekly exercise bouts logged was evaluated individually, 28.6% of the subjects increased and 53.6% of subjects decreased the number of weekly exercise bouts performed from fall to winter. The remaining 17.9% of subjects maintained the number of exercise bouts performed within 0.5 exercise bouts/wk. When evaluated by time logged, 42.9% of subjects increased and 42.9% of subjects decreased training time from the fall to winter. The remaining 14.3% of subjects maintained their total training time (within 15 min) between seasons. The even distribution of individuals who increased or decreased logged training time may be due to the heterogeneous nature of this sample of Masters-level skiers. Interestingly, of the individuals who decreased training time from fall to winter, 10 were women while only two were men. Although the results of this study show no significant changes in training volume between seasons, further investigation is warranted.

While Esteve-Lanao and colleagues (2005) reported sub-elite endurance runners averaging only 275 min/wk. during the six months preceding competition, Nimmerichter et al. (2011) reported elite cyclists averaging 890 min/wk. during their 11-month cycling year. Interestingly, competitive Masters-level skiers' weekly training volume seems to fall somewhere in between the runners' and cyclists' average weekly training time. The differences in training volume may be partially due to age, increased need for

physiological recovery, available time to train, or fitness level of the athletes (Maharam et al. 1999; Seiler and Tønnessen 2009). However, the major difference in weekly training time can most likely be attributed to the difference in total exercise load and the necessity for technical entrainment between sports (Seiler and Tønnessen 2009). Therefore, it is critical to also consider the distribution of the training intensity.

Training Intensity

Heart Rate Training Zones. It has been repeatedly shown that HR_{max} decreases and resting HR increases with age across populations (Faff et al. 2007; Tanaka et al. 2001). However, endurance training helps to maintain lower resting heart rates and slow the decrease in HR_{max} (Faff et al. 2007; Notton et al. 2004; Tanaka et al. 2001). Therefore, a modified regression equation ($APMHR = 208 - [0.7 \cdot \text{age}]$) was used to predict HR_{max} within this sample of Masters-level skiers (Tanaka et al. 2001).

The significant increase in HR_{avg} (117 to 123 for fall and winter, respectively; bpm) and $\%HR_{avg}$ (68.9% to 72.7% APMHR for fall and winter, respectively) suggests a corresponding increase in overall training intensity as the ski season progressed. While HR_{avg} was dependent on actual HR_{max} , $\%HR_{avg}$ was dependent on APMHR. Although the consistent increase between seasons helped validate the use of APMHR as a marker for maximal training intensity, there were a number of subjects who exceeded their APMHR during the fall or winter training periods. Eleven subjects and 15 subjects recorded maximum HR (HR_{MaxR}) values greater than their APMHR during the fall and winter seasons, respectively. Maximum recorded HR as a percentage of APMHR ranged

from 88% - 111% ($98.7\% \pm 5.0\%$, $M \pm SD$) during the fall season and 92 - 112% ($99.8\% \pm 5.0\%$) during the winter season. Only eight subjects reached HR values above APMHR during the BMT race ($98.3\% \pm 4.6\%$). Overall, 20 subjects recorded a HR value above APMHR during the fall, winter, or BMT collection periods. Assuming the HR data collected was accurate, HR_{max} was underpredicted in over 70% of the subjects despite using the modified APMHR equation.

The present study used percentages of APMHR as the cut-points for the training intensity zones (Z0 – Z5). Therefore, the underprediction of true HR_{max} must be taken into consideration when interpreting the training intensity results. Despite this limitation, the significant decrease in the percentage of training time in Z2 and increase in the percentage of training time in Z4 demonstrated an increase in training intensity from the fall to winter seasons.

The decrease in relative training time spent in Z012 and subsequent increase in the percentage of training time spent in Z345 support the original hypothesis that training intensity would increase from the fall to winter seasons. A similar pattern has been observed in other populations of competitive athletes. Zapico and colleagues (2007) found that elite male road cyclists significantly reduced their percentage of time spent training at low intensities and significantly increased their percentage of time training at high intensities as they shifted from the preseason (winter) to the pre-competition (spring) season. However, these results have not been universal within the Masters population. For instance, Neal and colleagues (2011) found much smaller changes in Masters-level triathletes' training intensity in the 2-4 months and 0-2 months preceding competition.

Future studies on competitive Masters-level cross country skiers would greatly benefit from more accurate training intensity cut-points based on physiological biomarkers (e.g., VT, LT, or VO_{2max}).

A Threshold or Polarized Approach to Training? In the absence of physiological biomarkers, threshold training was defined as a hard, yet attainable intensity that simulated endurance race-pace (> 10 km). Therefore, it can be reasoned that a subject's threshold HR was similar to that observed during the 2014 BMT. Average HR as a percentage of APMHR during the BMT ranged from 83.0% to 104.3% of AMPHR (134-172 bpm), which corresponded to HR training zones 4 and 5, respectfully. It therefore made sense to compare the percentage of training time spent in zones 0, 1, 2, and 3, combined, versus the percentage of training time spent in zones 4 and 5 combined when evaluating the distribution of training within each collection period. The average percentage of training time spent in training zones 0 - 3 combined was $74.8\% \pm 16.2\%$ and $62.5\% \pm 17.6\%$ for the fall and winter data collection periods, respectively. The average percentage of training time spent in training zones 4 - 5 combined was $25.2\% \pm 16.2\%$ and $37.5\% \pm 17.6\%$ for the fall and winter, respectively. Whereas the fall training period followed a more polarized training model, with $>70\%$ of training time spent below threshold intensity, the winter training period seemed to follow a threshold approach to training (Neal et al. 2011; Seiler and Kjerland 2006).

The winter training intensity distribution of competitive Masters-level cross country skiers was similar to that observed for Masters-level triathletes (43 ± 3 years of age) (Neal et al. 2011). Neal and colleagues (2011) discovered that the triathletes spent

69 ± 9% of their total training time below LT₁, 25 ± 8% between LT₁ and LT₂, and 6 ± 2% above LT₂ during the 6-months preceding the Ironman competition. These findings are consistent with the observation that recreational athletes tend to train harder than intended on long-slow training days, and easier than intended during threshold and interval sessions (Foster et al. 2001; Seiler and Tønnessen 2009).

Type of Training Approach. Heart rate data tend to underestimate total training load on athletes due to the delayed cardiovascular response during short-duration, high-intensity activities (e.g., speed workouts, high-intensity intervals, and resistance training) (Achten and Jeukendrup 2003; Seiler 2010; Seiler and Kjerland 2006; Seiler and Tønnessen 2009). Therefore, the type of training approach was also used as a means of evaluating exercise bouts based on the overall goal of each bout performed during the winter training season. This method was based upon Seiler and Kjerland's (2006) session-goal approach, which was used to evaluate the physiological load of training on national-caliber, junior-level Nordic skiers. The session-goal analysis was shown to be a better predictor of average oxygen consumption than HR data alone because it accounted for the potential lag in HR and underestimation of physiological exertion that occurred when the athletes performed interval or threshold training.

The percentage of time spent performing below-threshold activities (65.3%±4%; M±SE) was similar to the time spent in zones 0, 1, 2, and 3 combined. Whereas Seiler and Kjerland (2006) found a distinct increase in the percentage of time junior skiers performed high-intensity training when applying the session-goal approach, the type of training approach used in the present study revealed little change in high intensity

training. The type of training approach was limited by the subjects' understanding of the type of training definitions listed in the training log (Appendix B). Future studies would benefit from using this approach with an organized Masters-level training group in which each exercise bout had a predetermined training goal.

Boulder Mountain Tour Ski Race

Age and BMT Race Speed. In accordance with previous research, age was a significant predictor of race performance (Leyk et al. 2007; Menard and Stanish 1989; Young et al. 2008). It has been well documented that there is an inevitable decrease in endurance performance beyond an athlete's physiological peak. In an early study on Masters athletes, Menard and Stanish (1989) observed decreases in overall marathon running performance as athletes aged beyond their physiological peak. Similar declines in marathon race performance (2.6% – 4.4%) have been observed in endurance athletes after reaching age 50, despite controlling for confounding factors such as decreases in training and physical activity (Leyk et al. 2007).

While it can be assumed that Masters age-group winners train and race to their maximal athletic potential, various researchers have shown that athletic potential is limited by age-related performance factors such as decreased cardiac output, maximal oxygen uptake (VO_{2max}), and power output (Lazarus and Harridge 2007; Suominen 2011; Zamparo et al. 2012). Maximal oxygen uptake is a major determinant of endurance performance (Holloszy 2001; Kennedy and Bell 1996; Leyk et al. 2007, Tanaka and Seals 2008). Unfortunately, despite any amount of endurance training, VO_{2max} will

eventually decrease with age (Brooks et al. 2005). According to Holloszy (2001), changes in maximal cardiac output account for the majority of the 1% decrease in VO_{2max} per year (from age 35-70) in Masters-level endurance athletes. However, it is important to note that the degree to which VO_{2max} declines with age is still debated (Leyk et al. 2007). While some researchers have suggested a decline of less than 5% per decade, others have reported declines closer to 15% (Bortz and Bortz 1996; Leyk et al. 2007; Marti and Howald 1990).

Race Heart Rate Data and BMT Race Speed. Average HR during the first 30 minutes, the last 30 minutes, and throughout the entire BMT ski race significantly and positively correlated to race speed in the BMT. The higher an individual's average HR during the BMT, the better their race performance. These findings are similar to the results of an observational HRM study conducted on six male athletes (31 ± 5.9 years) during a 55 km cross country ski race (Kennedy and Bell 1996). Kennedy and Bell (2006) found that average race HR and absolute VO_{2max} both significantly correlated to race performance, whereas average race HR as a percentage of HR_{max} , relative VO_{2max} , VT_1 and VT_2 did not. It is important to note that, because BMT HR_{avg} as a percentage of APMHR did not significantly correlate to race speed, much of the difference in BMT HR_{avg} may be attributed to age.

When HR_{avg} was evaluated during different periods of the race, there was a tendency for average HR to increase from the first 30 minutes of the race to the last 30 minutes (136 ± 9 and 146 ± 12 bpm, respectively). It is unlikely that the increase in HR was due to the race course profile since the majority of uphill climbing occurred during

the first 10 km of the race. Therefore, the increase in race HR may have been due to one of more of the following: an increase in overall effort as the racers neared the finish, changes in snow or wax conditions near the end of the course that forced the athletes to work harder in order to maintain race speed, or the physiological phenomena of cardiac drift (Bilodeau et al. 1994; Buhl et al. 2001; Jeukendrop and Van Diemen 1998). Cardiac drift tends to occur in most individuals during long periods of exercise and is characterized by an increase in HR despite a steady external work rate (Jeukendrop and Van Diemen 1998). In studies by Kindermann et al. (1979) and Mognoni et al. (1990), 20-60 minutes of exercise caused heart rate to drift upwards by as much as 20 beats per minute (bpm) despite a constant work output. Additionally, the researchers observed steady or decreasing plasma concentrations during this same time period, indicating that while the external physiological load did not change, the heart muscle had to work harder to maintain its output.

Winter Training Volume and BMT Race Speed. Researchers have found that current training practices account for more variation in athletic performance than age alone (Tarpinning et al. 2004; Young et al. 2008). Whereas winter training time recorded on the HRM significantly and positively correlated to race speed, fall training time recorded did not. Removing three outliers from the winter training time vs. race speed graph greatly improved the strength of the correlation. These three outliers consisted of two men (50 and 60 yrs.) and one woman (51 yrs.) who trained slightly below the average winter training HR as a percentage of APMHR (64.5% - 68.4% vs. 72.9%). All three individuals performed 8-10.5 exercise bouts per week, higher than the

average 6 bouts/week, in addition to recording more weekly training time on their HRM than any other subjects during the winter collection period (736-1005 min/wk.). Despite the fact that these skiers spent considerably more time training, their race speed was not appreciably faster than the other study participants.

Although increased training time generally leads to better performance, there is a point where excessive training can lead to injury, overreaching, and ultimately overtraining syndrome (Maharam et al. 2009; Seiler 2010; Tanaka and Seals 2008). Additionally, it has been suggested that Masters-level athletes may require less total training volume, more recovery time, and adequate high-intensity training to maintain performance (Maharam et al. 2009).

Winter Training Intensity and BMT Race Speed. The percentage of winter training time spent at higher training intensities (Z4, Z5, Z345, and Z45) significantly and positively correlated to race speed, whereas the percentage of time spent at lower training intensities (Z1, Z2, and Z012) significantly and negatively correlated to race speed. Moreover, the total winter training time spent above 70% of APMHR (Z345) accounted for approximately 41% of the variance observed in race speeds across subjects.

Contrary to the findings presented in this study, Esteve-Lanao and colleagues (2007) found that a low-intensity training program was significantly more effective at improving race performance than a moderate-intensity training program. Over the five months preceding the competition season, 12 sub-elite endurance runners participated in either a low-intensity (subthreshold) or moderate-intensity (between thresholds) training

program. While both groups improved performance as a result of training, the low-intensity group saw greater improvements overall (Esteve-Lanao et al. 2007).

It has been suggested that the amount of time athletes spend training at low intensities correlates to improved race performance during endurance competition (Esteve-Lanao et al. 2007; Esteve-Lanao et al. 2005; Guellich et al. 2009). The contradictory findings observed in the present study of Masters-level skiers may have been due to differences in subject age, baseline fitness levels, or the physiological training load placed on the body during various exercise modalities. Moreover, there may be an upper limit to the amount of high-intensity training these athletes can perform before becoming injured or overtrained. Therefore, further research is necessary to determine the optimal distribution of training intensity for improved performance by Masters-level athletes.

Interestingly, the three skiers who were removed from the winter training time vs. race speed graph performed a greater percentage of time training in zones 0 – 3 (90.9% - 84.9%) versus zones 4 and 5 (15.1% – 19.1%) during the winter season. This training distribution was more similar to those found by Seiler and Kjerland (2006) in that the vast majority of training time was spent performing low-intensity training. However, whereas the junior skiers in Seiler and Kjerland's study were top competitors in their field, the three outliers from the present study did not experience exceptionally high race speeds as a result of their winter training patterns. This further emphasizes the fact that Masters-level skiers race performance benefits from a greater percentage of training time

spent at higher intensities. It would be interesting for future researchers to implement an experimental study on training intensity and race performance within this population.

Conclusions

The Masters-level cross country skiers in the present study maintained weekly training volume but increased training intensity from the preparatory (fall) to the pre-competition (mid-winter) seasons. This shift in training intensity corresponded to the skiers following a more polarized training model during the preparatory period and a threshold-based model during the pre-competition season. Additionally, the amount of time spent training at higher intensities during both the preparatory and pre-competition seasons significantly and positively correlated to BMT race speed. While characterizing the training practices of competitive Masters-level cross country skiers helps build the knowledge base necessary for improved coaching of this unique population, further observational and experimental research is warranted.

CHAPTER FOUR

CONCLUSIONS

In order for coaches and athletes to develop effective training strategies, current training practices of the population must first be understood (Kennedy and Bell 1996). Although optimal training distributions have been determined in elite and sub-elite endurance athletes, research on Masters-level cross country skiers has been largely overlooked in previous scientific literature. Therefore, the purpose of the present study was to observe the distribution of training volume and intensity within this unique population of athletes.

The 28 Masters-level skiers monitored during the present study increased their weekly training intensity but maintained their weekly training volume from the fall (preparatory) to mid-winter (pre-competition) seasons. Moreover, the skiers' distribution of training intensity within each season tended to follow a moderate-intensity, threshold based model as opposed to the polarized model followed by elite and sub-elite endurance athletes. Whereas age significantly and negatively correlated to race speed, average race heart rate, mid-winter weekly training volume, and absolute time spent training at higher-intensities (during both the fall and mid-winter collection periods) significantly and positively correlated to race speed. Interestingly, the percentage of weekly training time spent at lower intensities during the fall season significantly and negatively correlated to race speed.

While the characterization of these seasonal training practices helps to build the knowledge base necessary for improved coaching of this unique population, further observational and experimental research is warranted. Future studies would greatly benefit from HR training zone cut-points based of physiologically biomarkers determined from laboratory testing. Lastly, an experimental design, in which the distribution of training intensity and volume are controlled, may help determine a more optimal training distribution for competitive Masters-level cross country skiers.

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APPENDICES

APPENDIX A

SUBJECT CONSENT FORM

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT
MONTANA STATE UNIVERSITY- BOZEMAN

Project Title: Characterization of Seasonal Training Intensity in
Competitive Masters-Level Cross Country Skiers

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Project Funding: This study is NOT a funded project.

Purpose of this Project:

This project is being conducted to evaluate the seasonal training and racing practices of Masters-level cross country skiers in order to begin building the knowledge base necessary for improved coaching and training of this unique population. You are being asked to participate in a research project that involves both wearing a telemetry-based heart rate monitor and maintaining an exercise training log over the course of two 14-day sessions (early-fall and mid-winter seasons) as well as during a 32 km skate ski race (2014 Boulder Mountain Tour, Sun Valley, ID). Each participant is presented with this Informed Consent Document which explains the purpose of the testing, as well as risks and benefits associated with participation. Since your own plans already include training for and participating in the upcoming 2014 Boulder Mountain Tour skate ski race, all that you are being asked to do is wear a heart rate monitor and fill out the accompanying exercise training log.

General Project Outline:

There is no cost to you (the participant) and participation in this research project is voluntary. If you agree to participate you will be asked to attend a local information session during which you will learn how to use your heart rate monitor and record exercise data in your training log. You will collect and record exercise data for 14 days during the early-fall training season. Upon completion of the initial collection period, you will immediately return your heart rate monitor system and training log to the Project Directors, Emily Ranta and Tara Vetrone, for initial data analysis. This can be done in person or via standard mail. The second data collection period will begin in early January as soon as you receive your heart monitor and training log. You will collect and record your training *through* the completion of the Boulder Mountain Tour on February

2nd, 2014. The project directors will be collecting the heart rate monitor systems immediately following the 32 km skate ski race. You will be asked to email your completed Excel-based training log to the Project Directors; handwritten training logs may be delivered in person or returned in standard mail.

Utilizing the Heart Rate Monitor:

The heart rate monitor has two parts: 1) The chest strap (which measures and transmits heart rate activity), and 2) the wrist watch (which displays and records heart rate data). Using the instructions provided to you as a guide, you will be asked to don the heart rate monitor chest strap for every exercise bout over the course of each collection period as well as during the Boulder Mountain Tour ski race. The wrist watch can be worn on either wrist and may be worn over or under your upper body clothing. Once you initiate heart rate recording at the start of an exercise bout you are not obligated to do anything else - Simply perform your workout/race as you would normally. Upon completing each exercise bout you will be asked to end the heart rate collection period, the data will save automatically.

Utilizing the Training Log:

Each exercise bout must be accompanied by a corresponding training log entry. You may log your entries directly in the Excel template or, if you prefer, you may print the training log spreadsheet and record your exercise bouts by hand. You will be asked to document the date, start and end time, mode of exercise (e.g., running, biking, roller skiing, weight lifting etc.), duration of exercise (number of minutes for each exercise bout), and the overall goal of your training session (e.g., intervals, base training, recovery, tempo or race-pace, etc.). Additionally, you will record rating of perceived exertion (RPE) and global training intensity for each exercise bout (which will be explained during the MSU information session).

Potential Risks:

Since you are already planning to travel to Sun Valley, ID, to participate in the Boulder Mountain Tour, the risks associated with actually participating in this project are minimal. The most likely risk is that of mild discomfort from wearing the heart rate monitor chest strap while exercising and racing. With proper fitting, however, this discomfort should be no more than minimal. Regardless, we will work with you to make all possible adjustments, and minimize discomfort, during the initial informational session prior to your 14-day collection period.

Subject Compensation:

Upon completion of the Boulder Mountain Tour, you will receive a PDF file via e-mail of your own recorded heart rate (as a graph) from all recorded exercise bouts over the course of both collection periods. In addition, we will randomly select four study participants from those who have completed all aspects of this study and reimburse their Boulder Mountain Tour entry fee (up to \$100). Winners for this drawing will be notified shortly after the weekend of the Boulder Mountain Tour.

Benefits:

There are no direct benefits to you as a volunteer for this project. However, the Project Directors, Emily Ranta and Tara Vetrone, are willing to discuss the interpretation of your own test results. You may contact Emily or Tara at any time to discuss this option further.

Emily Ranta: Phone (651)230-2025; E-mail: emily.ranta@msu.montana.edu

Tara Vetrone: Phone (207)730-3289; E-mail: tara.vetrone@msu.montana.edu

Confidentiality:

The data and personal information obtained from this project will be regarded as privileged and confidential. Your heart rate data and training log will not be released to anyone else except upon your written request/consent. Your right to privacy will be maintained in any ensuing analysis and/or presentation of the data by using coded identifications of each person's data.

Freedom of Consent:

You may withdraw consent for participation in writing, by telephone, or in person without prejudice or loss of benefits (as described above). Participation in this project is completely voluntary.

In the UNLIKELY event that your participation in the project results in physical injury to you, the Project Director will advise and assist you in receiving medical treatment. No compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of your participation in the project. Additionally, no compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of traveling to training sites or the ski race, or for appointments with lab personnel at Montana State University. Further information regarding medical treatment may be obtained by calling the Lab Director, Dan Heil, at (406)994-6324. You are encouraged to express any questions, doubts, or concerns regarding this project. The Project Directors will attempt to answer all questions to the best of their ability prior to any data collection. The Project Directors, Emily Ranta and Tara Vetrone, fully intend to conduct the study with your best interest, safety, and comfort in mind. If you have additional questions about the rights of human subjects you can contact the Chair of the Institutional Review Board, Mark Quinn, at (406)994-4707 or mquinn@montana.edu.

SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT
MONTANA STATE UNIVERSITY- BOZEMAN

Project Title: Characterization of Seasonal Training Intensity in
Competitive Masters-Level Cross Country Skiers

Project Directors: Tara Vetrone, BS
Phone: 207-730-3289; E-mail: tara.vetrone@msu.montana.edu

Emily Ranta, BS
Phone: 651-230-2025; E-mail: emily.ranta@msu.montana.edu

Lab Director: Dan Heil, PhD, FACSM
Department of Health & Human Development
Montana State University
Phone: 406-994-6324; E-mail: dheil@montana.edu

Project Funding: This study is NOT a funded project.

Name: _____
Gender: Male / Female
Age: _____
Email: _____
Phone Number: _____

STATEMENT OF AUTHORIZATION

I have read the above and understand the discomforts, inconvenience, and risks of this study. I, _____ (*print your name*), agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signature of Participant

Date

Project Director

Date



APPENDIX B

EXERCISE TRAINING LOG AND REFERENCE TABLES

Figure A.1. Sample training log used by the subjects throughout the fall and winter collection periods.

Participant Name		Participant Study ID#		Name of Study?									
				Characterizing the Training Habits of Competitive Masters Skiers in the Pacific Northwest									
Week #1			Start Date: Jan. 2, 2014										
HRM?	DATE	Type of Activity	Type of Training	START Time	STOP Time	Total Duration (minutes)	Session RPE (1-10)	Zone 0 (minutes)	Zone 1 (minutes)	Zone 2 (minutes)	Zone 3 (minutes)	Zones 0-3 Total Time	Comments about your daily workouts...

Table A.1. Descriptions of training log components supplied to the subjects for reference purposes while completing the accompanying training log. The same definitions were used during the fall and winter collection periods.

Training Log Component	Description of Training Log Component
Day of Week	Each row corresponds to information for a single workout.
Type of Activity	The type of activity you performed during this workout - e.g., Running, rollerskiing, cycling, hiking, swimming, resistance training, flexibility training, Pilates class, yard work etc.
Type of Training Definitions	<p>Low-intensity recovery - light aerobic exercise that is designed to act as "active recovery". Zone 1.</p> <p>Long Distance - Typically a lower intensity endurance session that is at least 60 minutes in duration. Zone 1.</p> <p>Mixed Endurance - A longer workout with some type of harder intensity mixed in, sometimes in an unstructured fashion. Fartleks are a good example of this. Zone 2.</p> <p>Threshold Training - Otherwise known as "lactate threshold". A purposeful workout that is comfortably hard for a set duration of time (e.g., 20-50 minutes). Zone 2.</p> <p>Interval Training - A workout that incorporates sets of time intervals at harder work rates. For example, 1 minute hard, 2 minutes easy recovery, for a set number or duration of time. Overall rating for this should be Zone 2 when factoring in the easy recovery bouts.</p> <p>Speed Training - Very short, very hard exercise bouts. Can be incorporated in the middle of a workout, or alone. Hard speed bouts typically last between 30 seconds to 3-5 minutes. Zone 3.</p> <p>Resistance Training - Weight or strength training. This is always Zone 3.</p> <p>Other - Activity of daily life that is higher than resting energy expenditure (i.e. lawn mowing, Pilates, yoga, etc.) Specify activity. Zone 1.</p>
START Time	The approximate clock time when you started your workout (e.g., 10:00 AM).
STOP Time	The approximate clock time when your workout ended (e.g., 12:00 PM).
Total Duration	Total time (in minutes) between the START and STOP times (e.g., from 10:00 AM to 12:00 PM gives 2 hrs., or 120 min).
Session RPE	This is your perception of the average intensity of the entire workout using the 10-point scale in the "RPE Chart" tab.
Training Zones (0 to 3)	<p>Zone 0 - Easy Zone.</p> <p>Zone 1 - Comfortable to Comfortably-Hard Zone. You are able to talk some.</p> <p>Zone 2 - High Intensity Zone. You are at a race pace zone, going as hard as you can maintain for the intended duration</p> <p>Zone 3 - Very High Intensity Zone. Above race pace at the most maximal effort you can possibly perform.</p>

Table A.2. The rating of perceived exertion (RPE) scale supplied to the subjects for reference purposes while completing the accompanying training log. The same scale was used during the fall and winter collection periods.

RPE Scale	Intensity Description	Intensity Descriptions and Examples	RPE-ZONE EQUIVALENTS
0	Resting	Sitting or standing quietly at rest.	RPE 0 represents Zone 0
1	Very Easy	An RPE of 0.5 to 2.5 represents light intensity activities (e.g., flexibility exercises, Pilates, or yoga) and many activities of daily living (e.g., walking the dog or mowing the lawn with push mower). These activities often last less than 1 hour. An RPE of 3.0 to 4.0 represents most "base training" activities that are performed for 1+ hours as training without undue fatigue.	RPE 1-4 represents Zone 1
2	Easy		
3	Moderate		
4	Somewhat Hard		
5	Hard	An exercise intensity at which talking becomes difficult, such as during a threshold exercise session.	RPE 5-6 represents Zone 2
6		Race-pace for a longer endurance race (e.g., 34.4 km BMT)	
7	Very Hard	RPE of 7 to 9 represents interval intensities lasting less than 2-3 minutes each. Very fatiguing. Resistance training, weight training, or plyometric training.	RPE 7-10 represents Zone 3
8	Very, Very Hard		
9	Nearly Maximal		
10	Maximal		